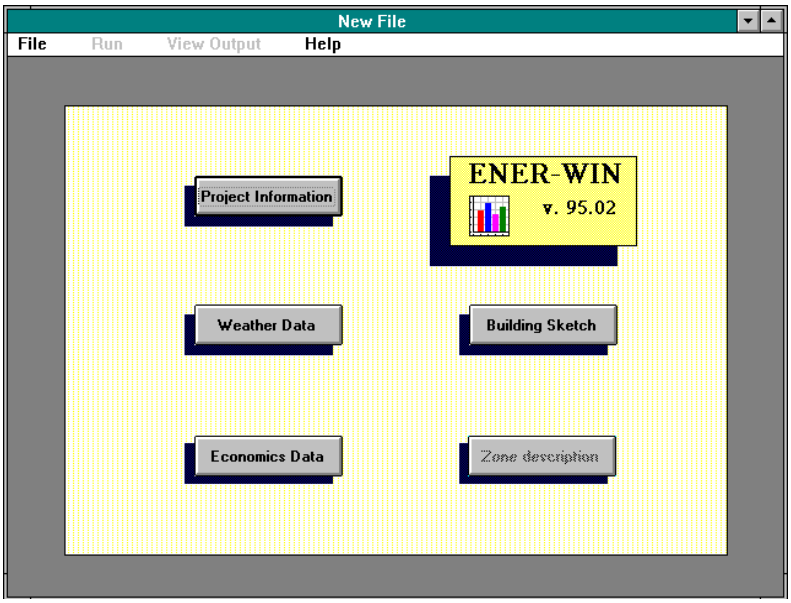
VITAL SIGNS

WHOLE BUILDING ENERGY PERFORMANCE - SIMULATION AND PREDICTION FOR RETROFITS



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Whole Building Energy Performance - Simulation and Prediction for Retrofits

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ABSTRACT

This resource package consists of concepts and methods to predict whole building energy performance using an energy simulation model and on-site measurements. The purpose of these analyses is to support retrofit design strategies for existing commercial buildings. The software portion is an energy simulation model using a visual interface developed in Visual Basic under the Windows(tm) programming environment. It permits the student to take field measurements from a building site and quickly enter these into the computer program through a sketching interface, numerous pull-down dialog boxes and pre-cataloged wall, roof, and window assemblies.

The field component of this package involves investigating, measuring, and recording the building's geometric features and energy parameters — such as, HVAC zoning, thermostat setbacks, ventilation and occupancy profiles, and lighting density and schedules. The educational value of the exercise is to involve the student directly with the realities of matching on-site measured energy data with computer simulated results, and further, to realistically predict the value of savings that an energy strategy upgrade would bring about.

This resource package consists of simulation software that runs under Windows(tm) and several forms for quantity take-offs and energy consumption recording.

OVERVIEW

Introduction

The issue of energy performance of buildings is of great concern to building owners because it translates to cost. More and more, the building owners expect that their buildings will be energy-efficient. Therefore, the designer has to keep the design feasible, both technically and economically, while responding to the local climate.

There are some frequently asked questions about energy-efficient buildings: Do the buildings really save significant amounts of energy compared to "conventional" buildings? How do they save energy compared to "conventional" buildings? Do energy-efficient buildings cost more to build? Do they reduce the annual operating cost enough to pay back the added investment in a reasonably short period of time?

To answer these questions, one should compare the energy use for cooling, heating, and lighting in energy-efficient buildings to those in "conventional buildings". In other words, it is important to trace the energy performance of the building after it has been built and operated in order to see if the building actually saves significant amounts of energy compared to the condition if the building were not built as an energy-efficient building. In many cases, actual building energy use can exceed that projected by calculations. These discrepancies are usually caused by two problems: unanticipated building use patterns and simulation tool limitations. Of the two, unanticipated building use patterns seem to contribute most to the discrepancy. For instance, the actual building operation hours sometimes exceed expectations and thus the actual energy use is much larger than that predicted.

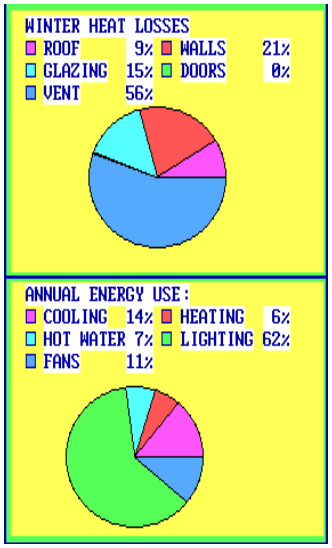


Figure 1: In the earlier stages of a design process, one can estimate the energy consumption of the building being designed, either by hand calculation or computer simulation. The results, as shown in this firgure, can give the designer an idea on the breakdown energy use in this building. Using these preliminary results the designer can then improve the energy performance of the building.

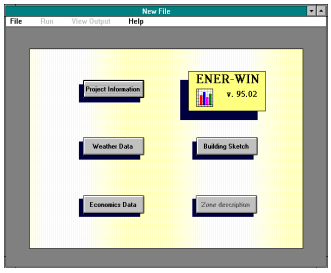
(Output from EnerCAD program, Texas A&M University)

In the earlier stages of a design process — either in a new or a retrofit design — estimation of the energy consumption using hand calculations can give general design direction. However, to obtain a more precise estimation, an hourly energy simulation using a computerized tool should be used. A computerized tool is capable of simulating various situations that will affect the energy results, such as the building use patterns, building shape and materials, and the weather conditions. It is also capable of performing cost-benefit analyses to see if the energy savings can pay back the added cost that was invested to make the building energy-efficient.

This course package covers the use of field evaluations and computer simulations for better understanding of the principles of energy-efficient buildings, especially commercial buildings. This package is intended to be applied to improvement of existing buildings or retrofit designs. Students using this package should have a prior introduction to active and passive energy systems in buildings.

Energy Prediction Methods

Often, the causes of excessive building energy consumption and high utility bills cannot be determined by a cursory site inspection or even a review of utility records. When this situation presents itself to an architectural designer, there is an elusive challenge in identifying the cause(s) of the problem and, furthermore, in designing a solution to the problem. Explicit techniques are required to reliably identify a building's energy problem. The best known technique is to apply both field measurements and computer simulations. It is important that students be made aware of field measuring techniques and how each of the building's features and properties affects overall energy consumption.



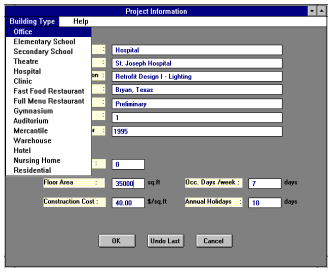


Figure 2: These figures show two of the ENER-WIN screens. ENER-WIN is the hour-by-hour energy simulation program that is used in this package. Supported with easy-to-use features and numerous pull-down menus to access the databases, ENER-WIN permits the student to evaluate the building's energy performance multiple times while still in the design process.

Both simplified and detailed simulation models can be used for energy predictions. Simplified energy analysis procedures are fast, yet they tend to take short cuts in the energy calculation methods and usually are not sensitive to design features that cause differences in hourly heat flows (e.g., as roof overhangs or louvers would influence the solar heat gains through windows as the sun angle changes through the hours of a day). With the currently available microprocessor speeds, it is viable to use detailed energy simulation models to investigate alternative energy design strategies and to utilize these methods in the classroom. This resource package includes one such hourly energy calculation model that runs under the Windows operating system on DOS-based microcomputers. The program's calculation turn around time is short enough to permit students to evaluate energy consumption multiple times while in the redesign stages.

The computer model employs a statistical weather data generator that determines hourly values of sun angles, solar heat gains, interior daylighting levels, conducted heat gains/losses, and infiltration gains/losses.

Disaggregation and Calibration

In building retrofits, whole building energy use is complex to measure and simulate. While the physical building features can modeled in a computer program, the operational characteristics can seldom be defined precisely. This can lead to questionable results in the computer simulations of energy use. One way of reconciling differences between the "real" building and the "simulated" building is to calibrate the simulation model through disaggregation of measured energy use, and then "tune" the simulation model to measured data. The goal of this calibration process is to match the total and the categories of energy use between the predicted results and the actual data. This is achieved by adjusting the simulation inputs so the model will adequately represent the building's actual energy use. This procedure assures agreement on a "base case", enabling the designer to build a variety of scenarios that depart from the base case with the confidence that energy impacts of new design changes will be accurately represented in their appropriate proportions to the whole building energy use.

There are several ways to obtain the data on the building's actual energy consumption. One quick way is by using the monthly utility records of the building that are usually available from most utility companies. Using a procedure that will be described in this package, one can then "disaggregate" these utility bill records into the component of heating, cooling, fan motor, lighting, equipment, and water heating energy. These are the values that will be used to calibrate the energy simulation model.

Objectives

Generally, the objectives of the assignment contained in this package are:

- *To create an understanding of the impact of building features on energy consumption,*
- *To sensitize the student to evaluation methods for real buildings, and*
- *To involve the student with methods of energy audits and retrofit design strategies.*

Specifically, this project will involve the student with:

- *Gathering of field data describing a building's physical and operational characteristics,*

- *Disaggregating of utility bill data into end use components,*
- *Preparing input and evaluating energy consumption using simulation software,*
- *Correlating measured building energy data with that predicted by software, and*
- *Realistically predicting the value of savings that an energy strategy upgrade would bring about.*

FIRST ORDER PRINCIPLES

Importance of energy simulation in architectural design

The building's form and thermal characteristics largely govern the amount of energy consumed by a building. Thus, it is the building designer who has the primary control over the building's energy use. When an architect starts to design a building, she or he is simultaneously starting the design of the heating, cooling, and lighting of the building. To avoid major flaws of the design, an architect need to include the evaluation of the building's energy consumption in the earlier stages of the design process. If energy efficiency is not adequately considered during these stages, higher operating cost will accrue over the life of the building.

In early design stages, either in new or retrofit designs, one can estimate the energy consumption of the building being designed by using hand calculations. However, an energy simulation program can help the designer have more reliable predictions because it is able to simulate the building, the weather conditions that obviously influence the thermal behavior of the building, and the operating schedules of the building. Energy simulations can then help the designer validate the preliminary estimation of the building's energy consumption and correct some of the architectural features of the building, and the mechanical systems, to improve the energy performance of the building.

Principles of the hourly energy simulation modeling techniques

There are two commonly used approaches for energy modeling — simplified methods and detailed methods. The simplified methods use integrated weather representations, like degree days or degree hours, to predict the building's response to the exterior environment. They also use integrated totals of interior loads, like kwh of lighting and appliance energy, to predict the internal heat gains. These models obtain the advantage of speed by avoiding detail, but by doing so, they sacrifice accuracy in the energy predictions. They are unable to accurately predict energy impacts of features that have large hourly fluctuations. For example, they cannot accurately predict the quantities of solar heat gain through windows that might have unique shading characteristics. Window heat gains can have large variations from hour to hour as the incident sun angle changes. Thus, the effects of using different shading devices are difficult to predict with simplified models. It is also difficult to accurately predict the impacts of using daylighting dimmers in building interiors, because electric lighting dimmers that respond to daylight levels are sensitive to hourly changes of sun angles and cloud cover. Interior variables are equally important. It is difficult to predict the energy impacts of variations in a building's operation schedule — i.e., changing the lighting on-off cycles, ventilation schedules, people occupancy schedules, and thermostat settings that change hourly.

The second method of energy modeling, the detailed method, literally performs a whole-building heat loss/heat gain calculation every hour of the year. When this calculation is done, it accounts for exact sun angles, cloud cover, wind, temperature, and humidity on an hourly basis. In doing so, the method can also account for effects of thermal time lag and thermal storage in the building's interior. Using these detailed calculations, one can study the effects of internal thermal mass, solar shading devices, computerized thermostatic controls, daylighting dimmers, occupancy sensors, and any other parameter that responds to hourly stimuli.

One extra burden of detailed models is that they require access to hourly weather records. Several national organizations have devoted much effort into the generation of hourly weather data that is "representative" of the climate in a specific location. The "typical" weather data files will normally contain hourly records of temperature, solar radiation, and wind data. These data are published in magnetic medium and are available is several formats — TRY (Test Reference Year), TMY (Typical Meteorological Year), and WYEC (Weather Year for Energy Calculations). The model used in this resource package, however, does not require the student to obtain these sources of weather data. Further information on the above published weather data sources can be found in the Annotated Bibliography, while the explanation of the weather data used in the simulation model of this package can be found in Level 3A section (a) of the Protocols for Field Evaluation and Computer Simulation.

As recently as several years ago, the hourly simulations were prohibitively time consuming on microcomputers and were therefore restricted to mainframe processors. Use of simplified methods often prevailed because the user could run simplified models on the office microcomputer. This allowed for reasonable accuracy when doing a "standard" building, but meant avoiding the evaluation of "special" building features, some of which were mentioned above. With the advent of faster microprocessors, however, most detailed energy models can be comfortably run on the ordinary microcomputer. There is no longer a reason to take the "short cut" to get faster answers, and we no longer have to sacrifice accuracy when we use the standard microcomputer.

In the evolution toward placing detailed energy models on microcomputers, many of these had the old "mainframe style" of input/output, i.e., tedious, unfriendly, and unwieldy in output. The recent trend has been to write user-friendly interfaces to the detailed simulation models, and to write interpretive software to capture the results and display them in a more graphic form. This has broadened the acceptance of the use of energy simulations, especially by architects, but possibly the more obvious reason for increased use of energy simulations is the mandating of energy codes and required certification of building compliance. ASHRAE Standards 90.1 (non-residential), 90.2 (residential), and 100 (retrofits) are now being adopted in most U.S. states as the codes to which new and existing buildings must comply.

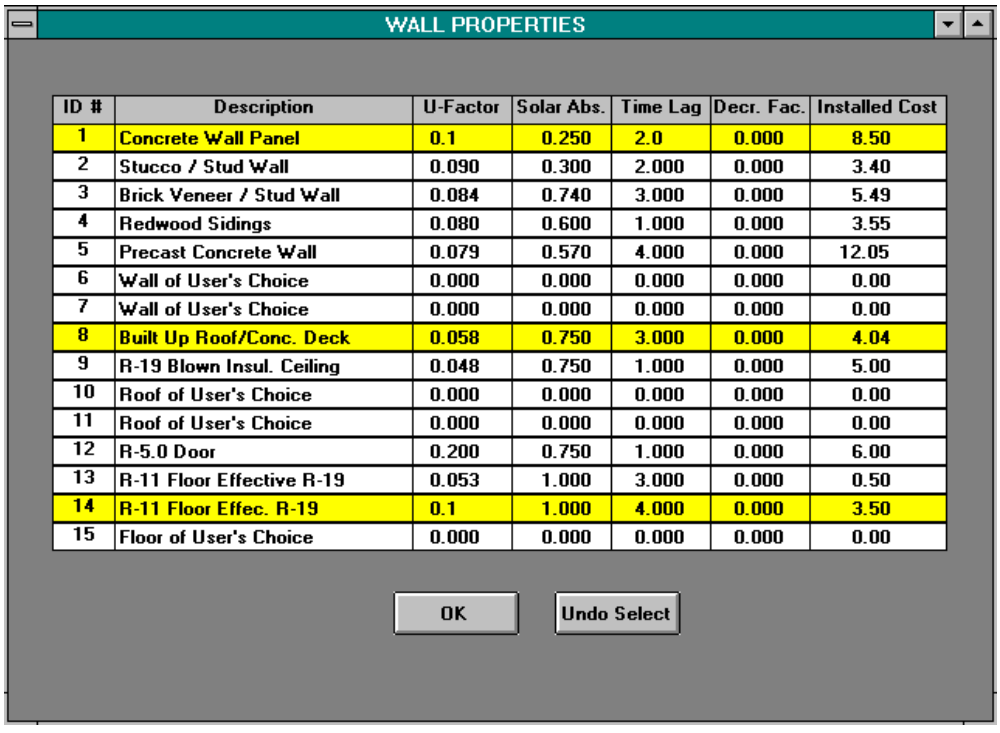
The software portion of this resource package is a detailed hourly energy simulation model using a visual interface developed under Visual Basic to run under Windows. This software permits the student to quickly enter the building data - taken from the field measurements - into the program through a sketching interface, numerous pull-down dialog boxes and pre-cataloged wall, roof, and window assemblies. This visual interface is a new innovation that promises to make the software more "natural" for architecture students who lack experience in building energy parameter specification and building material selection.

This software only requires simple inputs and is supported with defaulted values for building envelope's thermal properties, economics parameters, and various use schedules. The software provides default values and schedules for up to 15 building types. These schedules include: occupancy schedule, domestic hot water schedule, ventilation schedule, lighting and equipment schedule and temperature settings. The user can specify up to 99 HVAC zones, 20 different wall and window types, and 400 wall surfaces/

orientation combinations in one run. The software is supported with a statistically-based weather database for 270 U.S. and foreign cities.

The numerous input parameters mentioned above are pre-designed into the program to represent "normative" values and therefore tend to be taken for granted by the student. It is important to recognize, however, that many of the default assumptions have a critical role in determining the annual energy consumption in a building (e.g., the lighting power density and fan static pressure). The student should recognize that changing these parameters may dramatically impact the energy consumption, and that such changes should be made only after a thorough understanding of the system fundamentals has been achieved. For example, an enormous amount of heating and cooling energy can be saved by keeping interior temperatures at 50F in the winter and 85F in the summer, but would anyone tolerate it? More energy can be saved by lowering the lighting power from 2.5 watts per square foot to 0.5 watts per square foot — but can anyone say how this can be done and still give the occupant enough light to see? So, when altering any simulation parameter, the user must thoroughly examine the side effects of such alterations, and then only proceed with changes after the effects have been determined to be practical and permissible to the building occupants.

The key element to bear in mind when using a simulation model is that the model is presumed to react accurately to stimuli, so the stimuli (the inputs) must conform to reality and these are under the control of the user.



ID #	Description	U-Factor	Solar Abs.	Time Lag	Decr. Fac.	Installed Cost
1	Concrete Wall Panel	0.1	0.250	2.0	0.000	8.50
2	Stucco / Stud Wall	0.090	0.300	2.000	0.000	3.40
3	Brick Veneer / Stud Wall	0.084	0.740	3.000	0.000	5.49
4	Redwood Sidings	0.080	0.600	1.000	0.000	3.55
5	Precast Concrete Wall	0.079	0.570	4.000	0.000	12.05
6	Wall of User's Choice	0.000	0.000	0.000	0.000	0.00
7	Wall of User's Choice	0.000	0.000	0.000	0.000	0.00
8	Built Up Roof/Conc. Deck	0.058	0.750	3.000	0.000	4.04
9	R-19 Blown Insul. Ceiling	0.048	0.750	1.000	0.000	5.00
10	Roof of User's Choice	0.000	0.000	0.000	0.000	0.00
11	Roof of User's Choice	0.000	0.000	0.000	0.000	0.00
12	R-5.0 Door	0.200	0.750	1.000	0.000	6.00
13	R-11 Floor Effective R-19	0.053	1.000	3.000	0.000	0.50
14	R-11 Floor Effec. R-19	0.1	1.000	4.000	0.000	3.50
15	Floor of User's Choice	0.000	0.000	0.000	0.000	0.00

Figure 3: ENER-WIN, the energy simulation program that is used in this package, is supported with various databases for the thermal properties of the wall, roof, window, and skylight assemblies. This figure shows the catalogs for wall/roof assemblies in ENER-WIN. The user can modify or change the thermal properties and installed cost of the assemblies according to the actual data.

EQUIPMENT

This field evaluation makes use of an existing history of utility data and the results from an energy simulation tool. Together, these will establish the normative behavior of the whole building energy use patterns. Further simulations can identify the individual components of energy use and allow for close examination of specific energy impacts of building envelope assemblies or mechanical equipment parameter changes. On-site data collection includes interviews with the building manager to obtain occupancy patterns and HVAC zone definitions, lighting levels, wall surface temperatures, solar access diagrams, and building dimensions. Typical measuring equipment includes:

- *Minolta T-1H illuminance meter*
- *Omega portable infrared thermometer*
- *MS-DOS notebook computer with energy software*
- *LOF sunangle calculator*
- *Solar access mask sheets*
- *Suunto handheld inclinometer*
- *Suunto handheld bearing compass*
- *Tape measures*
- *Electronic tape measure*
- *Balloons and cord*
- *Step ladder*
- *Video camcoder*

APPLICABLE STANDARDS AND CODES

The most prominent standards that relate to energy efficiency in buildings in the U.S. are those developed by the American Society of Heating, Refrigerating and Air-conditioning Engineers (ASHRAE). The ASHRAE energy standards for buildings have been, and continue to be, adopted into codes for various states and municipalities. These standards provide sets of guidelines for the energy-efficient design of new and existing buildings and building systems. The guidelines are designed to promote the application of cost-effective design practices and technologies that minimize energy consumption without sacrificing either the comfort or productivity of the occupants.

During the early years of energy awareness that began with the oil embargo by the OPEC nations, the primary concern was “energy independence” through reduction of our fossil fuels. Since then, our attention has been redirected toward environmental and economic issues. But, regardless of the focus, the net result of the efforts are the same — i.e., to reduce energy consumption in buildings. The objectives of the energy standards are:

- *To set minimum requirements for the energy-efficient design of new and existing buildings and construction,*
- *To provide criteria for energy-efficient design and methodologies for measuring projects against these criteria, and*
- *To provide guidance in designing energy-efficient buildings and building systems.*

ASHRAE Standard 90.1 (1989) is extremely broad in scope, encompassing almost all new construction (except low-rise residential) in all climates across the U.S. The requirements of the standard are both general and conservative. They do not represent the most cost-effective level of energy conservation for each and every project. The designer is encouraged to consider these standards as a starting point, consider the interrelationships of different building elements and systems, and seek designs that exceed the standard. Accordingly, the standard presents recommendations in addition to its requirements. Standard 90.1 applies to the building envelope, energy distribution, systems and equipment, heating, ventilation, air-conditioning, lighting and energy management. Included with the standard are two user-friendly software programs that perform the calculations to check compliance with the standard. These are **ENVSTD** (envelope system performance) and **LTGSTD** (lighting system performance).

The **ENVSTD** program calculates and verifies the thermal values for proposed wall, roof and foundation configurations to ensure compliance with the ranges allowed by the standard. The **LTGSTD** program performs lighting power density compliance calculations for a maximum of 500 building spaces and 100 exterior illumination areas. The programs need an MS-DOS compatible microcomputer, with at least 384K RAM memory.

ASHRAE Standard 90.2 (1993) sets forth design requirements for new low-rise residential buildings for human occupancy. For the purposes of this standard, "low-rise residential buildings" include single-family houses, multi-family structures of three stories or less, manufactured houses (mobile homes), and manufactured modular houses. This standard does not include hotels, motels, nursing homes, jails, and barracks. It does cover the building envelope, heating equipment and systems, air-conditioning equipment and systems, domestic water-heating equipment and systems, and provisions for overall building design alternatives. Compliance to this code can be through either a prescriptive path or an annual energy cost method.

ASHRAE Standard 100-1995 covers energy conservation in existing buildings. Its purpose is to conserve nonrenewable energy resources in existing buildings by establishing methods for operating and maintaining buildings, monitoring building energy use, implementing recommendations from energy audits, and determining and reporting compliance. Specifically, the standard is directed toward: (a) upgrading the thermal performance of the building envelope, (b) increasing the energy efficiency of the energy-using systems and components, and (c) providing procedures and programs essential to energy-conserving operation, maintenance, and monitoring.

SMACNA (Sheet Metal & Air-conditioning Contractor's National Association) also publishes energy efficiency standards related to building systems and air duct construction standards — Energy conservation guidelines (1984), Energy recovery equipment and systems, air-to-air (1991), and Retrofit of building systems and processes (1982).

ANNOTATED BIBLIOGRAPHY

AMERICAN SOCIETY OF HEATING, REFRIGERATING, AND AIR-CONDITIONING ENGINEERS, HANDBOOK OF FUNDAMENTALS, ASHRAE 1993, ATLANTA.
This is the standard reference text covering almost any fundamental aspect of thermal control design. Used until careworn by engineers and architects alike, it is recommended reference. Available in paperback through student membership in ASHRAE.

BURT HILL KOSAR RITTELMANN ASSOCIATES & MIN KANTROWITZ ASSOCIATES, COMMERCIAL BUILDING DESIGN. INTEGRATING CLIMATE, COMFORT, AND COST. , VAN NOSTRAND REINHOLD, 1987, NEW YORK.
The issues that relate to the energy use in commercial buildings are covered in this book. The main emphasis is on the relationship between climate, comfort, and cost. Several commercial buildings and their problems are discussed in details.

COWAN, H. J., HANDBOOK OF ARCHITECTURAL TECHNOLOGY, VAN NOSTRAND REINHOLD, 1991, NEW YORK.
This handbook provides a sorely needed contemporary guide to materials, technologies, and techniques. Written by 25 specialists, this autorative volume distills the most important parts of today's existing knowledge into one concise, practical resource. The book includes mathematics, physics, and chemistry of building materials. Other major topics include: loads, energy savings due to daylighting, and other building equipment.

DEGELMAN, L.O. "A STATISTICALLY-BASED HOURLY WEATHER DATA GENERATOR FOR DRIVING ENERGY SIMULATION AND EQUIPMENT DESIGN SOFTWARE FOR BUILDINGS", PROC. BUILDING SIMULATION '91, INTERNATIONAL BUILDING PERFORMANCE SIMULATION ASSOC. (IBPSA), AUGUST 20-22, 1991, NICE, SOPHIA-ANTIPOLIS, FRANCE.
This paper describes an operating hourly weather simulation model which is utilized to drive building energy simulation and equipment design software. This weather simulation model is used by ENER-WIN, the hourly energy simulation program for this resource package. This paper discusses the input/output features for this weather simulation model, the weather data generation methods, and the model validation.

DEGELMAN, L.O., "ENERCALC: A WEATHER AND BUILDING ENERGY SIMULATION MODEL USING FAST HOUR-BY-HOUR ALGORITHMS", PROC. 4TH NATIONAL CONFERENCE ON MICROCOMPUTER APPLICATIONS IN ENERGY, APRIL 25-27, 1990, TUSCON, AZ.
This paper describes the algorithms of an operating hour-by-hour building energy simulation model. This simulation model is used by ENER-WIN, the energy analysis program for this resource package. The model employs a weather data compression technique and streamlined heat transfer algorithms to permit rapid energy analyses on large multizone buildings under varying climatic conditions. This paper describes the heat gain/loads algorithms in this simulation model.

LECHNER, NORBERT., HEATING, COOLING, LIGHTING. DESIGN METHODS FOR ARCHITECTS JOHN WILEY & SONS, 1991, NEW YORK.
This book was written by an architect to help other architects find the most relevant information and practical tools when designing heating, cooling, and lighting systems. The design tools are mainly concepts, guidelines, handy rules of thumb, examples, and physical modeling. The book promotes a three-tier approach: load avoidance, maximal use of a building's natural energies, and use of mechanical equipment. It offers in-depth qualitative rather than quantitative approaches.

MEYER, WILLIAM T., ENERGY ECONOMICS AND BUILDING DESIGN., MCGRAW-HILL, 1983, NEW YORK.
This book is meant to be a comprehensive introduction to the art and science of energy-conscious design. Estimating methods for mechanical engineering input discussed in this book are intended to provide approximate answers for use during preliminary and schematic design. The goal of this book is to enable a designer to ask better-informed questions and permit some energy analyses during schematic design so that bounds may be placed on the energy problems and more focus may be given to the concern of energy use in the architectural components of a building.

MOORE, FULLER., ENVIRONMENTAL CONTROL SYSTEMS. HEATING COOLING LIGHTING., MCGRAW-HILL, 1993, NEW YORK.
This book introduces the concepts of controlling the thermal and luminous environment in buildings. The comfort of the occupants is the central determinant of the design. The book covers basic physical principles, human response, and design response to site and climate -- both in passive and mechanical systems. The basic quantitative procedures through use of worksheet calculations are also introduced.

SOEBARTO V. I. & DEGELMAN, L. O., "AN INTERACTIVE ENERGY DESIGN AND SIMULATION TOOL FOR BUILDING DESIGNERS", PROC. BUILDING SIMULATION '95, INTERNATIONAL BUILDING PERFORMANCE SIMULATION ASSOC. (IBPSA), AUGUST 14-16, 1995, MADISON, WI.
This paper describes ENER-WIN, the energy analysis program that is used in this resource package. The paper presents, in details, the fundamental concepts, technical basis and capabilities of the software; the weather generation; the methods of describing the building; load calculations; and the program output.

STEIN, B. & REYNOLDS, J. S., MECHANICAL AND ELECTRICAL EQUIPMENT FOR BUILDINGS., 8TH ED., JOHN WILEY & SONS, 1991, NEW YORK.
The book covers all major components in building systems, qualitatively and quantitatively. It explains principles of passive and active systems, load calculations, lighting and daylighting, acoustics, mechanical transportation, and sewage systems. Numerous standards and data from ASHRAE Handbook are also included.

TAMU., ENER-WIN USER'S MANUAL, COLLEGE OF ARCHITECTURE, TEXAS A&M UNIVERSITY, 1995, COLLEGE STATION.
This manual provides a step-by-step guidance on how to use the ENER-WIN computer program for energy analyses. Explanations of how the program operates are also given. Each input screen of the program is presented to ease the user in learning and using the program.

WATSON, DONALD & LABS, KENETH., CLIMATIC BUILDING DESIGN. ENERGY-EFFICIENT BUILDING PRINCIPLES AND PRACTICE., MCGRAW-HILL, 1983, NEW YORK.
This book provides an excellent introduction and reference guide to climatic design, the art and science of using the beneficial elements of nature -- sun, wind, earth, air-temperature, plants, moisture -- to create comfortable, energy-efficient, and environmentally wise buildings. It also discusses how to evaluate local climate in any region of the country, how to determine climatic design strategies, and how to take advantage of the environment and climatic conditions such as natural ventilation, earth-sheltering, and solar heating.

MICROCOMPUTER SOFTWARE FOR ENERGY CALCULATIONS

ASEAM-2 (DOS), ACEC RESEARCH AND MANAGEMENT FOUNDATION, WASHINGTON, D.C.
ASEAM-2 is a modified bin method procedure for calculating heating and cooling loads and energy consumption figures for residential and small commercial buildings. The input and calculation procedures are divided into Loads, System, and Plant segments. A variety of output runs, many by month and by hour, can be specified by the user. ASEAM-2 is an instructional building energy design tool for both engineering students and practitioners.

COMPLY 24 (DOS), GABEL DODD ASSOC., BERKELEY CALIFORNIA.
COMPLY 24 is a flexible, easy-to-use computer software package designed to quickly test and document compliance of buildings with the latest California Title 24 Building Energy Efficiency Standards. From a building description entered only once, the program instantly checks compliance with the Residential and/or Nonresidential Standards; displays the effects of building, lighting and/or HVAC system changes; and calculates zone-by-zone heating and cooling loads.

DAYLIT (DOS), U.C.L.A., LOS ANGELES, CALIFORNIA.
DAYLIT is a daylighting design tool for the schematic design stage. It has a similar format to the Solar 5 software described below.

EEDO (DOS), BURT HILL KOSAR RITTLEMAN ASSOCIATES, BUTLER, PENNSYLVANIA.
EEDO calculates heating and cooling energy requirements for new houses. It also performs economic optimization for energy related retrofits. For retrofit analysis, the program provides a sequenced list of energy options that should be used under the given economic criteria. The program models active and passive solar systems. The special features of the program are extensive on-line help, dynamic defaults, graphic and tabular output.

ENERCAD (DOS), TEXAS A&M UNIV., COLLEGE STATION, TEXAS.
EnerCAD (Energy-based Computer Aided Design) uses the Variable-Base Degree-Hour energy analysis method, and is mainly intended for quick annual energy performance estimates of commercial buildings. Buildings are assumed to be single zone with little or no internal mass. The program features a user-friendly interface to create a building. The run mode results in an annual energy use calculation. It also derives the annual utility bills broken into categories of use.

ENERPASS 3.0 (DOS), ENERMODAL ENGINEERING, WATERLOO, ONTARIO, CANADA.
ENERPASS 3.0 simulates the energy consumption and thermal performance of most building types. The program calculates heat flows within the building, between the building and ambient air, and between the building and the ground, on an hourly basis (based on weather data which is supplied with the program). User interface is simple. Most options are selected from menus, and operating schedules for building occupancy, lighting, water usage and equipment operation are defined by graphical input. The user can also building custom libraries of HVAC equipment.

ENERGY SCHEMING 2.0 (MACINTOSH), UNIVERSITY OF OREGON, EUGENE, OREGON.
ENERGY SCHEMING is specifically created to help the designer at the schematic design stage. The user defines the building by drawing it and not by numeric input. Menus make the selection of design options easy, and graphic output helps the designer visualize the consequences of the various strategies chosen.

ENER-WIN (DOS-Windows), TEXAS A&M UNIV., COLLEGE STATION, TEXAS.
ENER-WIN is the Windows version of ENERCALC, an hourly energy simulation model for estimating annual energy consumption in buildings. It features an interactive graphical interface for input and output. The simulation model uses streamlined algorithms that permit hour-by-hour energy calculations in minimal time. It is in compiled FORTRAN-77 and features: transient modeling based on sol-air temperature, time lag, decrement factor, ETD; zone temperature based on internal thermal mass response factors; and daylighting algorithms based on a modified Daylight Factor methodology. ENER-WIN is supported with numerous default data bases and accommodates up to 50 user-defined profiles for occupancy, hot water, lighting, zone temperatures, and ventilation rates; up to 98 HVAC zones, 20 each of different wall and window types, and 400 wall surfaces/orientations/shading conditions in each run. The program package includes a weather database (30-year statistics) of 274 cities worldwide, features graphical and tabular output reports, and performs life-cycle (Present Worth) cost analysis.

MICRO-DOE2 (DOS), ERG/ACROSOFT INTERNATIONAL, INC., LITTLETON, COLORADO.
MICRO-DOE2 is a microcomputer version of the mainframe DOE-2 program, which performs energy use analysis for residential and commercial buildings. It is used for: the design of new-energy-efficient buildings; the analysis of existing buildings for energy-conserving modifications; and the calculation of design budgets. It is intended for use by architects and engineers with a basic knowledge of the thermal performance in buildings. It also includes menu-driven user interface and a run-time status display.

SOLAR5 (DOS), U.C.L.A., LOS ANGELES, CALIFORNIA.
Solar5 is a very user friendly program developed especially for use at the schematic design stage. The name of the program is a little misleading because Solar5 us a tool that enables architects to design more energy-efficient buildings rather than just "solar" buildings. The graphic output consists of a three-dimensional graph to relate time of day, time of year, and some other variable such as heat gain or loss through a south window. Changes in the design are immediately reflected in the shape of the three-dimensional graph and an experienced user can quickly understand the consequences of any design modifications.

VISUAL DOE (Windows), ELEY ASSOCIATES, SAN FRANCISCO, CALIFORNIA.
VisualDOE is a Windows application of DOE-2 program that enables architects and engineers to quickly evaluate the energy savings of HVAC and other building design options. It uses the DOE-2.1E hourly simulation tool as the calculation engine so that energy use and peak demand are evaluated on an hourly basis. VisualDOE makes it possible to evaluate different HVAC system types, daylighting, thermal energy storage, and central plan load management, through an easy-to-use graphic interface. The program is supported with on-line help system that explains the information tha the program needs to perform a simulation.

VITAL SIGNS

PROTOCOLS FOR FIELD EVALUATION & COMPUTER SIMULATION:
Whole Building Energy Performance

These protocols outline the activities at each level of investigation for the "Whole Building Energy Performance - Simulation and Prediction for Retrofits" Package. The protocols consist of three levels: (1) determining candidacy for full work-up through a brief visit, (2) preparing the project for energy modeling through several detailed surveys, and (3) executing and calibrating the energy simulation and analyzing retrofit strategies to improve the building's energy performance.

Each activity will be later described and supported with appropriate form(s) . Each team should consist of 2 to 4 students.

1 DETERMINING CANDIDACY FOR FULL WORK-UP

1A: PROJECT INFORMATION

In this level the students are required to obtain the general information about the building that will be analyzed. This information can be obtained by interviewing the building operator/manager and/or by briefly observing the building.

1B: BUILDING PHYSICAL DATA

During a brief visit, the students may wish to ask for the building drawings from the building operator or the architects. If drawings are not available, the students can sketch the building floor plan and section/ elevation, and record the building materials.

1C: UTILITY BILL RECORDS AND COSTS OF FUEL

The students are required to obtain the building utility records for a minimum of 12 contiguous months. These data can be obtained from the local utility company or from the building operator/manager. The students are also required to obtain the unit price of each type of energy or fuel used in the building.

1D: QUICK CALCULATION OF ENERGY USE

After the students are able to obtain the general information about the building, a quick calculation of the total energy use can be performed based on rules of thumb for disaggregated energy use.

2 PREPARING THE PROJECT FOR ENERGY MODELING

2A: ECONOMICS DATA

In this step, the students are required to obtain more detailed data of the economics parameters in the building, such as the building's economic life, the escalation rates of the fuel costs, the discount rate, and the demand charge.

2B: BUILDING DETAILS, THERMAL PROPERTIES AND OUTSIDE FEATURES

In this level, the students are required to conduct a detailed survey by visiting the building over a few weeks to obtain detailed information about the building's geometry, its thermal properties, and the conditions surrounding the building. These data can be obtained either from the building drawings, if available, or from the site measurements.

2C: OPERATING SCHEDULES AND BUILDING SYSTEMS

The students are required to record the building systems and the operating schedules. These will include the HVAC systems, lighting systems, water heating, and occupancy, and the profiles accompanying each system. This level can be conducted either by direct observations, measurements, or interviews with the building operator.

2D: ZONE DESCRIPTION DATA

Because in most buildings every room or zone has different characteristics, the students are required to observe each zone in the building. This detailed step requires a more detailed interview with the building operator, more detailed observations and field measurements.

2E: DISAGGREGATION OF THE ACTUAL ENERGY USE

This activity includes the disaggregation of the total energy use into the components of the energy and costs for fan motor operation, space heating, space cooling, lighting, equipment, and water heating. The results can then be compared to the previous results from level 1.

SIMULATING, CALIBRATING, AND RETROFITTING

3A: COMPUTER SIMULATION

This activity makes use of the energy simulation program to predict the current energy use in the building. The students are to enter the project data, which are collected in Levels 1 and 2, into the energy simulation program, and then run the energy simulation.

3B: CALIBRATION OF THE ENERGY SIMULATION MODEL

To accurately represent the real energy use in the building, the simulation model has to be calibrated against the actual data. This activity involves calibrating the predicted annual and monthly energy consumption to the actual annual and monthly energy use.

3C: RETROFIT STRATEGIES FOR IMPROVED ENERGY PERFORMANCE

After the simulation model reasonable represents the actual building, the students will be required to compare the results with a reference/target building and analyze the problems. Once the current energy problems are identified, the students should study and propose energy savings strategies. The students are then encouraged to conduct optimization of the proposed strategies.

3D: FINAL REPORT

At the end of these activities, the students are required to make a report that contains all of the project information, existing problems in the building that are related to the current energy use, and suggestions or recommendation to improve the building energy performance.

DETERMINING CANDIDACY FOR FULL WORK-UP

1A: PROJECT INFORMATION

FORM NO

1A.1

During a brief visit, interview the building operation supervisor(s) or the building manager to obtain the following data and use the provided form to record the data.

- *Building name and description:*
  Record the building name and a brief description that explains the building. Example: "Two-story office building with skylights and lightshelves".

- *Building type:*
  Choose the building type from the following selections:

- Office	- Clinic	- Warehouse
- Elementary School	- Fast Food Rest.	- Mercantile
- Secondary School	- Full Menu Rest.	- Hotel
- Theater	- Gymnasium	- Nursing Home
- Hospital	- Auditorium	- Residential

- *Building location (City and State):*
  Record the city and state names where the building is located.

- *Year of construction:*
  Record the year when the building was built.

- *Construction cost:*
  Record the construction cost in $ per square-foot, excluding the HVAC and lighting systems cost, walls, roofs, and windows.

- *Total floor area:*
  Record the total building floor area.

- *Total occupied days in a week and a year:*
  Record the number of occupied days during the week, the number of holidays in a year when the building is unoccupied, and the months when the building is vacant.

1B: BUILDING PHYSICAL DATA **FORM NO**

If possible, obtain the building drawings from the building operator/ manager or from the architect. Otherwise, measure the building's physical dimensions so the building sketch(es) can then be drawn.

a) Building's floor plan:

OUTSIDE:

- Measure building's perimeter.
- For each wall, measure the positions and dimensions of windows, doors, and adjacent walls.

INSIDE:

- Measure dimensions of each room.
- For the thickness of walls: go to door or window openings, and measure the wall thickness.
- Measure zone depths for daylighting uses.

b) Building's height/section/elevation:

OUTSIDE:

If possible, measure the building's height. If not, use the following methods:

- Use a person or a stick, whose height is known. Put it, or ask him/her to stand, very close to the building's wall. Estimate the building's height by determining multiples of the height of that person (or stick, etc.). 1B.1
- Use a helium balloon and tie it to a long cord. Hold the cord and let the balloon go up straight until it reaches the point where balloon is at the same height as the building. Put a mark on the cord. Pull the balloon down, and measure the distance between the balloon and the mark on the cord. 1B.1
- If the building has more than one story and all floors are the same height, just do the above step for one story, and then multiply the result with the number of the stories.

INSIDE:

If possible, measure the ceiling height. If not possible, follow the methods for measuring the building height outside.

To estimate the thickness of the floor for the second or higher floor, go to the stairwell area, and measure/estimate the floor thickness.

c) Sloped walls, windows, and roof:
Use inclinometer to estimate the slope of building surfaces.

d) Envelope assembly properties:
Define glazing types and sizes; wall, roof, and floor materials. Various sources for this type of information are: the on-site building survey, the as-built plans from the building manager's office or from the architect's office.

e) Adjacent buildings and obstructions:
Record data about adjacent buildings and natural objects. Include the objects size (width and height), its reflectance, and its transparency.

SKETCH THE BUILDING

1B.2

After the building physical data are obtained, either through site measurements or building drawings, sketch the building, according to the following guidelines, in the provided form.

- *Floor plan:*
  Sketch a separate plan for each level that is different. Clearly put the scale and/or the dimensions. Clearly note every zone. Zone is mainly based on the HVAC requirements, although a different space function and location may also define a different zone.
- *Other information:* Record the building orientation from North, the level number represented by your sketch and the total floors that are typical for this level (for multi-story buildings), total floor area, and average ceiling height for this level.
- *Surroundings:* Record the ground covers surrounding the building (e.g. grass, concrete, etc.). Also record any trees or other surfaces that may shade the building.

1C: UTILITY BILL RECORDS AND COSTS OF FUEL

FORM NO

1C.1

a) Utility Records:
Utility records must be available for a minimum of 12 contiguous months. Tabulate the monthly energy consumption and utility bills in terms of kwh for electricity and therms (or cubic feet) for gas consumption. Use the provided form.

b) Unit Energy Costs:
Before performing any calculations to disaggregrate components of energy use, determine the unit costs of the fuel. First, subtract all water service, sewer, and sanitation costs from the utility bill. Isolate the electric cost and divide it by the month's charge for electric kilowatt-hour usage, including fuel adjustment charges and taxes. The result will be the cost per kwh. There may also be a peak demand charge. This will be expressed as *$ per KW*. Isolate these values to be used later for the computer input.

For gas, determine the total therms (100's of cubic feet), or millions of Btus (1000's of cubic feet). Find the total gas cost and divide it by units of use. The result will usually be *$ per therm*, but you may also find *$ per million Btus*. Note that these can always be expressed in a consistent fashion — a therm is 100,000 Btus, or 100 cubic feet of gas.

1D: QUICK CALCULATION OF ENERGY USE

1C.1

The first assessment of whole-building energy performance can be accomplished by a quick calculation of the building's "Energy Utilization Factor" (EUF) simply by using the utility bill record and the building's gross floor area. From the utility bill record, you need to convert the kilowatt-hours of electric use to Btus and then add the Btus of gas use. The formula for EUF is expressed in terms of source Btus per square foot per year, and is expressed by:

$$\text{EUF} = \frac{\text{KWH x 10,500 + Therms x 100,000}}{\text{gross area (sq.ft.) x 1000}} = \text{Mbtus/sq.ft.}$$

(cont'd...)

QUICK CALCULATION OF ENERGY USE (CONT'D)

After the EUF is calculated, you need to compare this to the Building Energy Performance Standards (B.E.P.S.). Values for B.E.P.S. are based on geographic location and building type. In certain instances, the exact building type may not be represented among those in the B.E.P.S. table. For these cases, you should select one or more of the building types that appear to approximate the functions of the study building and average the values. An example of this will be shown later for the sample problem.

If it is discovered that the building's actual energy utilization, EUF, is greater than the target B.E.P.S, then the building is a good candidate for further investigation into retrofit strategies that might be applied. At this point you should continue with Level 2 -- to further describe the building -- and Level 3 -- to test the effects of various retrofit designs. If the target B.E.P.S. cannot be reached in a cost-effective manner, you should attempt to get as close to the goal as possible. However, it is possible that the B.E.P.S. target cannot be attained because of site factors or building use functions that were not anticipated when the B.E.P.S. values were derived.

PREPARING THE PROJECT FOR ENERGY MODELING

You are now required to obtain the more detailed data on the building. All of these data will be used as the input to the energy simulation program. The types of the data and the forms to be used to record these data are similar those in the energy simulation programs. This will make it easier for you when later you enter these data into the simulation program.

What you will collect in the visits over a few weeks are the economics data, the detailed building geometry and thermal properties, the operating schedules and settings, and the building systems and equipment loads.

2A: ECONOMICS DATA

FORM NO

Record the following data in the provided form. These data are required if Life-Cycle cost analyses are to be performed. 2A.1

- *Building economic life:* Record or estimate the investment life. Typically 10, 20, or 30 years.
- *Mechanical system life:* Record or estimate the expected life of the mechanical systems before replacement. Typically 15 years.
- *Discount Rate:* Estimate the annual rate of return on investment, in decimal fraction.
- *Building cost escalation:* Estimate the annual rate of escalation of building materials and construction, in decimal fraction.
- *Energy costs:* From the utility bills, record the unit price of each energy source, e.g. $/KWH for electric, $/therm for gas, and $/1000 gallon of water.
- *Energy cost escalation rates:* Estimate the annual cost escalation rate for each energy source, in decimal fraction.
- *Demand charge rate structure:* Show the structure of the demand charge. For example:

  $ 10.00/KW for first 20 KW
  $ 12.00/KW for next 50 KW, and
  $ 13.00/KW for remaining KW,

  will be illustrated as follows:

KW	$/KW
20	10.00
50	12.00
1	13.00

2B: BUILDING DETAILS, THERMAL PROPERTIES AND OUTSIDE FEATURES

FORM NO

a) Building Details

1B.2

Record all other building features that have not been covered during the brief visit(s). These may include external attachments such as overhangs, lightshelves, blinds, vertical fins, and/or basement and attic. Also observe and record any outside features such as trees and/or other buildings that may shade this building. Add these data to the sketch(es) you made earlier.

b) Thermal Properties of the Envelope

2B.1

Record the building envelope material assemblies and estimate their thermal properties. Record the information on the provided form.

- *Wall and Roof Properties:*
  Describe the wall/roof materials, U-Factor, Solar Absorptivity, Time Lag, Decrement Factor, and Installed Cost.
- *Window and Skylight Properties:*
  Describe the window/skylight materials, U-Factor, Solar Heat Gain Coefficient, Emissivity, Daylight Transmissivity, and Installed Cost.

Try to estimate these material properties by analyzing the material assemblies. You can also use the data from the literature as listed in the Annotated Bibliography. If you cannot determine all these properties, you may wish to use some default values from the catalog in the software. Decrement factor will be computed by the program if it is entered as zero.

These catalogs will later be used when you describe the walls/roof/windows/skylight of every zone.

c) Outside Features

1B.2

Observe and record any outside features such as trees and other buildings that may shade this building. Also record the type of the exterior ground surface(s). Using the references as listed in the Bibliography, try to find the reflectance factor of this exterior ground surface. Put all of this information on the building sketch you have made earlier.

2C: OPERATING SCHEDULES

FORM NO

Every function/zone in the building usually has different operating schedules and systems. Record and/or estimate all of these operating schedules and systems, and other important data specific for particular zones. If the same schedules and systems are used in other zones, you do not have to repeat this recording step for those zones.

These include the schedules of the occupancy/unoccupancy periods, hot water usage, ventilation, and lighting plus equipment. Also record the temperature settings during the occupied and unoccupied periods. Record the profiles of these schedules and settings on the provided forms. Assign a number of each profile you sketch for further reference. All of these data may be obtained from the inverview with the building operator/manager or from your own observations.

- *Operating Schedules Profiles:* 2C.1
  Sketch the 24-hour profiles in decimal fractions of the peak values. For example, if the building is fully occupied, the number is 1 (for 100 percent). If the building is half-occupied, the number is 0.5.

- *Temperature Settings:* 2C.2
  Sketch the actual 24-hour temperature settings in degrees Fahrenheit. Sketch these settings profiles for four different conditions: Summer occupied, Winter occupied, Summer unoccupied, and Winter unoccupied.

2D: ZONE DESCRIPTION DATA

Record all data for each zone you have defined. Sketch each zone and record all detailed data for that zone. These data will be required later when running the computer simulation. 2D.1

Record all of the building systems: HVAC, Lighting, Daylighting (if present), and Water Heating. A commercial building usually has a mechanical room for the HVAC equipment. Go to that room and record all necessary data such as the HVAC type(s), the fan motor power, and the efficiency of the equipment. Observe the lighting type(s) and measure the lighting level(s) in the building. Observe and record other equipment such as computers, copy machines, and coffee machines. Make an observation if the building utilizes daylight. If so, make note on how the electrical lighting is dimmed.
Use the Zone Description form to record these data, one form for each zone.

a) General Information about the zone: 2D.1

- *Zone Area:*
  Record the floor area of this zone. You can calculate this area from the drawing, or if drawings are not available you can estimate this by measuring the floor area on the site. Sometimes floor or ceiling tiles can be counted to estimate the zone area.

- *Internal Mass:*
  Estimate the average internal mass per square foot of floor area. For a commercial building this is approximately 100 psf, while for a wood frame residence this is about 50 psf. This is to include all interior floors, walls and furnishings.

- *Infiltration Rate:*
  Estimate the infiltration rate in Air Changes per Hour (ACH). Typical rates are:

  Tight skin construction: 0.2 - 0.6 ACH
  Medium skin construction: 0.6 - 1.0 ACH
  Loose skin construction: 1.0 - 2.0 ACH

Refer to Form 2C-1 and 2C-2

b) Schedules and temperature settings: 2D.1

Enter the correct profile number from the profiles you have sketched earlier for the occupancy, hot water, ventilation, and lighting & equipment. Put this number on the blank labeled "Profile No.". Do the same thing for the temperature settings, and put the numbers on the blank labeled "Temperature Setting No.". Also, record the peak value for each of the following parameters:

- *Occupancy:* Number of people in this zone
- *Hot Water:* Amount of hot water needed by a person in a day.
- *Ventilation:* Mechanical ventilation rate in CFM/person.
- *Lighting & Equipment:* Lighting load and equipment in Watt/sq.ft.

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c) HVAC Systems: 2D.1

Note whether the building uses economizer cycle and/or natural ventilation. Estimate the average airflow rate when natural ventilation is used, in CFM/sq.ft. The default value is 4 cfm/sq.ft.

Write the appropriate HVAC system type for this zone by selecting from the list in the following page. Record the cost, Fan Static Pressure, Cooling SEER, and Heating COP, if data are available.

- *Cooling:*
  1. Variable-Air-Volume (VAV)
  2. Double Duct
  3. Multizone
  4. Fan Coil Unit
  5. Roof Top Unit
  6. DX Residential
  7. DX Residential Heat Pump
  8. Window Unit

- *Heating:*
  1. Gas
  2. Electric Resistance
  3. Heat Pump

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d) Lighting systems: 2D.1

Write the lighting system type by selecting from the list below. Also write the lighting system cost in $/sq.ft.

- *Lighting:*
  1. Incandescent
  2. Fluorescent
  3. Halogen
  4. Mercury Vapor
  5. Metal Halide
  6. High Pressure Sodium
  7. Low Pressure Sodium

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e) Daylighting: 2D.1

When daylighting is utilized, write the room depth that is daylit and the target lighting level in footcandles. Also add the following:

- *Venetian Blind:* 1 if present, 0 if not.
- *Diffuse Shade Transmissivity:* Fraction of transmittance of diffuse blind.
- *Window Sill Height:* Height of window sill above floor, in feet.
- *Window Height:* Height of top of window above floor, in feet.
- *Ground Reflectance:* Luminous reflectivity of ground, 0 if unknown.

After you finish collecting and recording all of the above data, you basically can start evaluating the building by using the energy simulation program. However, before you execute the energy simulation program, perform the manual disaggregation steps in part 2E.

2E: DISAGGREGATION OF THE ACTUAL ENERGY USE

FORM NO

2E.1 - 2E.6

Using the monthly utility bill records, disaggregate the actual energy use in the building into the components of:

- *Energy and costs for fan motor operation.*
- *Energy and costs for lighting.*
- *Energy and costs for receptacles (e.g., computers, office equipment and small appliances).*
- *Energy and costs for water heating.*
- *Energy and costs for space cooling.*
- *Energy and costs for space heating.*

a) Fan motors.

2E.1

In a very small building, such as a residence, blower fans are not operated continuously because we can rely on infiltration to maintain healthy air for the occupants. Residential blower fans typically only operate when the HVAC unit is providing its heating or cooling function, and therefore the energy estimating can be aligned with the operation of the compressor or heater. So, a separate estimate of fan motor energy use is not necessary, and this step may be skipped. In a large building, however, fans are usually operated constantly while the building is occupied. This is to guarantee that code-mandated air quantities are always available to the occupants. It also makes the energy consumption prediction a relatively easy task. So, if you have determined that the building's air handling units are always functioning, then a fairly accurate estimate of the fan's energy consumption can be determined if you carefully record information from the fan unit's electrical name plate and make an accurate determination of the fan unit's hours of operation.

First, interview the building manager to determine the fan unit's operating schedule. It is possible that the fan unit never gets turned off, but it is more likely that is has a prescribed schedule that keeps it on only during occupied hours. Record this information for each fan unit in the building.

The next step is to record data from the fan unit's electrical name plate. On each fan unit, you will find a metal plate with electrical data stamped into it. What you should determine is the power (KW) of the unit while under full load. If the fan motor shows horsepower (h.p.), then record this and simply multiply by 0.75 to get KW. More than likely, however, the nameplate will show voltage and several current values. Voltage is usually shown as a range (e.g., 115-120V). You can usually determine which end of the range is typical for the building by

interviewing the building manager. The current values stamped in the nameplate are shown as *LRA* (Locked Rotor Amps), *RLA* (Rated Load Amps), and *FLA* (Full Load Amps). Select either the *RLA* or *FLA* as the average "running load amps". The *LRA* amps should not be used to estimate energy use, because this value represents a peak load that only occurs during a short spike when the unit is turned on. It is only important for sizing the fuse and wiring to the unit.

After the fan motor's voltage and current are recorded, then the power may be computed by the formula:

Power (KW) = Voltage (volts) x Current (amps) / 1000.

If the fan unit is constant volume, then this KW is also the average KW. If the fan unit is variable speed, however, then the KW should be estimated as the average between the power draws at its lowest and highest speeds. Multiplying the rated power by 0.8 would be an acceptable estimate of the average KW for the VAV air handling units.

The annual KWH can now be estimated with the equation:

KWH = Average KW x Total hours of operation.

The annual cost is simply the KWH multiplied by the average cost per KWH.

b) Lighting.

2E.2

This step will help you determine the energy used for lighting. First, examine the lighting fixtures and record the rated watts per lamp. Multiply the lamp's rated watts by 1.25 if the lamp is fluorescent (to account for the ballast power), but do not modify the value if the lamp is incandescent. Next, you will have to count all the lighting fixtures and the number of lamps in each fixture throughout the building. Multiply the watts per lamp by the total number of lamps in the building. This will give you the maximum watts of connected lighting power for the building interior. Divide by 1000 to get kilowatts.

Using the information from your interview with the building manager, establish the lighting pattern of the building. Determine the fraction of lights that are turned on for each hour of the normal week day, number of occupied days per week, and number of holidays per year. The fraction of lighting load for each hour of the normal day is called a *lighting profile.* You should plot this on a graph to have a graphic representation. It helps to add clarity to your work.

Add up all the fractions from the 24 hours in the lighting profile. This will be the equivalent full load hours of lighting use for each occupied day. Now, multiply this sum by the connected lighting kilowatts for the building. The result will be the number of kilowatt-hours of lighting use per each occupied day. Then, multiply this value by the number of occupied days per week and divide by 7. This will be the average lighting energy use per day. To get the annual electrical use for lighting, multiply by the number of non-holiday days per year. (Normally, for offices this will be 365-10, or around 355; but for restaurants or residences, it could be 365.)

If exterior lighting exists, perform a similar analysis for those lighting fixtures and use patterns and add this to the interior lighting energy use. The annual cost of lighting is simply the annual kwh multiplied by the average cost per kwh (determined earlier.)

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c) Receptacles. 2E.3

Receptacle loads consist of computers, office equipment, small appliances, and similar devices — usually on the order of 0.2 to 1.0 watt per sq.ft. in commercial buildings. In a residence, it would also include televisions, hair dryers, and refrigerators and may reach as high as 3 watts per sq.ft. In a restaurant or industrial building, the load would be even higher. Receptacle loads do **not** include HVAC equipment, fan motors or water heating equipment.

The receptacle load estimate is done in a manner very similar to the lighting energy calculations. You will first assess the types of equipment used, the power supplied to each device, and the numbers of each device. After adding up all the device loads, remember to convert watts to kilowatts by dividing by 1000. By doing this, you will be estimating the peak kilowatt load for all the receptacles. Normally, you can assume that receptacle use corresponds closely with lighting use, and therefore we do not need to derive a separate receptacle use profile. For purposes of this analysis, you may use the same profile as that used for lighting. Just multiply the kilowatt value by the number of hours of full load use, and the result is annual kilowatt-hours.

For some buildings there is a shortcut to the estimation of receptacle loads. If a building is heated by a non-electric fuel (typically gas or oil), and if there are identifiable months in which there is no cooling, then within the non-cooling months all the electrical energy is for fan motors, lighting, and receptacles. So, for those particular months, the receptacle energy is simply the total KWH from the utility bill minus the KWH estimated for fan motors and lighting. This is the preferred method of calculation, since you would already know that the electrical use within these months would be made up of those three uses. After one month's value is determined, the annual value may be estimated by multiplying by 12.

(Note: You have just derived the total kilowatt-hours for lighting and receptacle loads. As a supplement to your calculation procedures, it may be of interest to see how this part of the energy picture compares to established energy criteria. You can quickly derive the lighting and equipment *power density* by dividing total watts by the building's gross floor area. This value will be in the units of *watts per square foot*. ASHRAE's Standard 90.1 places a limit on this value for new buildings. You can use this as a checkpoint, but do not consider it as a requirement you have to meet. You are performing an audit of an existing building.)

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d) Water heating. 2E.3

From the software user's manual, determine the typical amount of hot water usage by each occupant for the type of building you are evaluating. This value can range from 1 gallon per person for typical office buildings to 20 gallons per person for residential buildings. Estimate the total annual hot water energy use and annual cost using the water heating equations below.

Annual Hot Water Energy Use:

$$\text{Q (Btus)} = \frac{\text{OCC} \times \text{GPD} \times 8.33 \times (140 - \text{TG}) \times \text{ODPY}}{\text{EFF.}}$$

where,

OCC = Number of building occupants.
GPD = Gallons per day per person of hot water use.
8.33 = Weight density of water (pounds per gallon).
140 = Hot water supply temperature (deg.F.).
TG = Ground temperature (usually equal to the average annual air temperature).
ODPY = Occupied days per year.
EFF. = Thermal efficiency of the water heater (typically 0.75 for gas, 1.0 for electric)

Annual Hot Water Energy Cost:

$$\text{Cost (\$)} = \frac{\text{Q (Btus)}}{\text{HV} \times \text{CPU}}$$

where,

HV = Heating value per unit (e.g., 3413 Btus per kwh).
CPU = Cost per unit (e.g., $ 0.08 per kwh).

Hot Water Equations. Annual hot water energy use and annual hot water energy cost can be estimated by using these equations.

(e) Space cooling.

2E.4

If the building is **gas heated**, then all the electric use that is not used for fan motors, lighting, receptacles and water heating will be assumed to be used for space cooling energy. To determine this value, simply total the annual electric use from the utility bills. Subtract from this total the electric use for fan motors, lighting, receptacles, and water heating (if any). The remainder will be attributed to space cooling. The costs then will be determined by the same method as used in step (a) above. Since the energy use by air handling units (blower fans) was determined earlier, the "cooling energy" is defined as compressor energy and, if present, the chilled water and condenser water pump energy. For air-cooled chillers, this energy represents the compressors and the condenser fan motors. The computer simulated results will also show separate values of energy use for fan motors and for the cooling compressor and/or the heater energy use. Go to step (f).

If the building is **electrically heated,** then the energy for space cooling must be disaggregated from that used for space heating. This can be estimated by first finding the months of heating/cooling neutrality (i.e., months in which there is not much need for either heating or cooling energy). The neutral months are those months in which we say the outdoor temperature is near the building's thermal **balance temperature**. For most commercial buildings, this would be the months in which the outdoor average dry-bulb temperature is between 40F and 50F. For residential buildings, it would be for the months in which the outdoor average dry-bulb temperature is between 55F and 65F. Study the climatic data to try to select the neutral months.

For the **neutral months**, first go back to steps (a) through (d) and estimate the motor, lighting, receptacle and water heating electric use for only those months. Just divide the annual use by 12 or multiply the daily use by the actual days in each neutral month. In any event, after adding the total electric use for motors, lights, receptacles, and water heating, subtract this from the total electric use in those same months. Assume that half of this total is for cooling and half is for heating. Tabulate the data accordingly.

For months with outdoor average temperatures **above the balance temperature**, sum all the electrical energy used for motors, lights, receptacles and hot water and subtract it from the total electric use. The result may be assumed to be for space cooling. The cost is determined by the same method as in step (a). Sum this and the amounts from the neutral months.

(f) Space Heating. 2E.5

If the building is **gas heated**, add up the total annual gas use. Subtract from this the amount of gas used for water heating. The remainder can be assumed to be used for space heating. Determine the cost by the same method as outlined in step (d) above. Go to part (g).

If the building is **electrically heated**, the amount for the **neutral months** has been determined as fallout from step (e) above. For months with outdoor average temperatures **below the balance temperature**, sum all the electrical energy used for motors, lights, receptacles and hot water and subtract it from the total electric use. The result may be assumed to be for space heating. The cost is determined by the same method as in step (a). Sum this and the amounts from the neutral months.

---

g) Energy Summaries 2E.6

Construct a summary table of categories: (a) fan motors, (b) lighting, (c) receptacles, (d) water heating, (e) space cooling, and (f) space heating. Show this breakdown in the pie chart on the provided form.

SIMULATING, CALIBRATING, AND RETROFITTING

Using the data collected from Level 1 and Level 2, analyze the building by using the energy simulation software for this package. Calibrate the simulation inputs to match the actual data. Analyze the current energy problems in the building, and study the retrofit designs that can improve the energy performance of the building.

3A: COMPUTER SIMULATION

FORM NO

The software provided with this course package is the ENER-WIN program which runs under Windows(R) on MS-DOS microcomputers. When this program is executed, it will provide the opportunity to specify the project information -- climate, economic parameters, fuel costs, occupancy and operating characteristics, system parameters, and a fully detailed description of the building's geometry and envelope assembly properties.

Refer to ENER-WIN User's Manual pp. 1 - 9.

Execute the ENER-WIN program, and have all data available. The following instructions will help you to get started. However, more detailed explanations can be found in the ENER-WIN User's Manual.

a) Main Menu

3A.1

Refer to ENER-WIN User's Manual pp. 10-13.

This is the main interface screen of ENER-WIN. It has two major types of menus: Pull-down and Command-button menus.

The Pull-down menus are: File (to start a new project or retrieve an existing project), Run (to run the energy simulation), View Output (to view the simulation output), and Help (to get on-line help).

The Command-button menus are buttons for: Project Information (to enter general information about the project), Weather Data (to select existing weather data or create new weather data), Economics Data (to enter economics parameter), Building Sketch (to sketch the building HVAC zones), and Zone Description (to enter all data in each zone).

To start a new project, it is better if you follow the following steps although you actually do not have to enter the data in a sequential order. To retrieve an existing project, click the "File" pull-down menu, select "Retrieve Old Project", and enter the project file name. Then you can start editing the project data by following the steps below.

b) Project Information

3A.1

Click the "Project Information" button in the Main Menu. This will bring you to the Project Information screen.

Input the information that ENER-WIN requires by entering the data you have recorded in form 1A-1 (Project Information). Because the data you have recorded are the same as the data that ENER-WIN needs, you can simply type in all of these data in the provided spaces.

Refer to ENER-WIN User's Manual pp. 14-15.

SUGGESTION: ENER-WIN is supported with numerous default values to ease your work. To enter the data more quickly, click the "Building Type" pull-down menu, and select from the list the building type that is suitable for your building. When you select a building type, the program will automatically install all default values for that building type. You can edit these values by using the actual data from your data collection.

Click the "OK" button to continue to the Main Menu

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c) Weather Data

3A.2

Refer to ENER-WIN User's Manual pp. 16-17 and Appendix C.

The second set of input you need to enter is the weather data. Click the "Weather Data" button in the Main Menu. For a new project, this will bring you to the weather database of ENER-WIN. Select a city name that best represents the location of your building (select the closest city if the building location is not listed in the weather database). The program will give you an opportunity to edit the values in the database (for further explanation please refer to the Appendix C of ENER-WIN User's Manual).

After you are done, you can view these weather data by clicking the Weather Data button once again. This will bring you to the Weather Data screen, and ENER-WIN will present you the following information: (1) city and state name, (2) latitude, longitude, Standard Time meridian, and elevation, (3) average dry-bulb temperatures and their standard deviations, (4) average daily maximum temperatures and their standard deviations, (5) average dewpoint temperatures and their standard deviations, (6) average daily solar radiation on horizontal surface, and (7) average wind velocity.

Click the "OK" button to return to the Main Menu.

---

d) Economics Data

3A.2

Entering the economics parameters of the building is necessary if you want to analyze the life-cycle cost of the building. However, you can run the energy simulation without entering or editing any of the inputs for the economics parameters. ENER-WIN has automatically entered these values when you selected a building type.

In this exercise, however, it is suggested that you enter the economics parameters of the building using the data you have recorded in form 2A-1. Click the "Economics Data" button. This will bring you to the Economics Data screen. Edit the default values and enter the values from your data collection.

Refer to ENER-WIN User's Manual pp. 18-19.

To enter the demand charge schedule, toggle the button for the demand charge to "Y" (Yes). ENER-WIN will present the demand charge screen, and you can enter the appropriate values.

Click "OK" to return to the Main Menu.

---

e) Building Sketch

3A.3

Refer to ENER-WIN User's Manual pp. 20-21.

The next step is to sketch the building HVAC zones. Click the "Building Sketch" button in the Main Menu. You will be presented with a sub menu where you can specify the number of different floor plans you are going to sketch. Then you can start drawing the building HVAC zones by using the data recorded in form 1B-2.

To prepare the geometrical parameters:
Enter the grid size, building orientation, ceiling height, and number of floors.

To draw the zones:
Click "Select Zone" on the menu. A row of 10 zone numbers will be presented and you are to select the zone number (color) you want to draw. Start drawing by dragging the mouse on the grid. Keep moving the cursor until you are done. To draw another zone, click "Select Zone" again and repeat the same steps but with a new color.

When you are done drawing one level, you can click "Next Level" to go back to the floor selection menu, When you are done drawing every level, go back to the main menu. You can later re-enter the Sketch routine if you want to make modifications.

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f) Zone Descriptions 3A.3, 3A.4

After sketching the building, you need to specify the parameters of every zone by entering all data you have recorded in forms 2B-1, 2C-1, 2C-2, and 2D-1. Click the "Zone Description" button in the Main Menu. A list of the zones in the building will be presented. Double click the zone you want to edit.

Refer to ENER-WIN User's Manual pp. 22-33.

To enter the schedule profiles and temperature settings: 3A.5
Use the collected data to enter the schedule profiles and temperature settings. First, click the "Profiles" pull-down menu and select the type of profiles you want to edit (Occupancy, Hot Water, Ventilation, Lights & Equipment, or Temperature Settings). Enter the correct values of these profiles using the data from form 2C-1 or 2C-2. Highlight the profile number applicable for the zone you are editing. When you are done, return to the Zone Description screen, and continue editing other profiles/settings.

To enter the wall and window properties: 3A.6
First, click on a wall number, then click the "Properties" pull-down menu in the Zone Description screen and select "Wall" or "Window" to go to the "Wall and Roof Properties" or "Window and Skylight Properties". Then, enter the wall/roof and window/skylight properties recorded in form 2B-1.

Refer to ENER-WIN User's Manual pp. 22-28.

To enter non-geometrical parameters: 3A.4
Use the data from form 2D-1 to enter the zone parameters. Enter the zone floor area and internal mass. Then enter the data on the number of people, hot water usage, ventilation rate, lighting type, cost, and load, equipment load, and HVAC system types. Also enter the appropriate numbers of the profiles or temperature settings you have entered earlier. Enter the data on natural ventilation and infiltration rate. Enter the data for daylighting if daylight is used in the building. Enter the data on the HVAC systems if data are available.

Refer to ENER-WIN User's Manual pp. 28-33.

To enter geometrical parameters: 3A.4
The bottom-half of the screen is provided for you to enter the geometrical and thermal envelope's data. The sketch program automatically computed the envelope sizes from your sketch of the building HVAC zones. However, you may wish to edit these values to add window sizes, shading characteristics, etc.

Using the data recorded in form 2D-1, enter the wall ID number(s), surface exposure(s) and window ID number(s). Also enter the shade factors of each wall. Enter the seasonal factor, and other window data required when daylighting is used in this zone.

Click "OK" when you are done to return to the Zone Menu. Double click another zone you want to edit and repeat the same process.

g) Run Energy Simulation 3A.7

When you are done entering the data of all zones, return to the Main Menu. You may now run the energy simulation program. Make sure that you save the data you have entered into a project input file.

Refer to ENER-WIN User's Manual pp. 34-37.

Then, run the energy simulation by clicking the "Run Simulation" pull-down menu. Select "Complete Run" to provide a complete simulation output. For a new project it is suggested that you accept the defaults in the Run Energy Simulation screen. Click "OK" to run the simulation.

Refer to ENER-WIN User's Manual pp. 38-44.

h) View Energy Simulation Output 3A.7

To view the simulation output, click "View Output" pull-down menu in Main Menu. Enter the name of the output file you want to view. You can also print this output file. Observe the monthly summaries, annual energy use, source MBtus/sq.ft. (EUF), and the breakdown of energy use.

3B: CALIBRATION OF THE ENERGY SIMULATION MODEL

3B.1, 3B.2

After the building project has been fully entered into the program, be sure the utility bill records for a 12-month period are available, and then calibrate the simulation model to the actual utility records. The calibration objective will be to match computer results to actual data for: (a) peak demands for whole-building electricity, (b) annual energy use in the six disaggregated categories, and (c) annual energy costs for electricity and gas.

In order to accomplish a “match” between computer results and actual data, careful attention must be paid to the placing of accurate data into the computer program. The data must comply as closely as possible to the site-collected information. Precision is critical for the building’s geometric features (i.e., dimensions and shape characteristics), building component thermal properties (wall, roof, and window conductance and solar transmission properties), internal profile descriptions (occupancy, ventilation, lights and temperature settings), and building system characteristics (heating/cooling C.O.P.’s, fan sizes, air distribution systems and controls).

a) Peak demands for whole-building electricity. 3B.1

Most utility districts will record the peak electric demand for each month. If these are available, examine the monthly summaries from the computer output to see if the monthly peak demands match the peak demands recorded by the utility company. If you are analyzing a residence, it is likely that peak demands are not recorded and you can skip this step.

If each discrepancy is more than 20%, then investigate the items that would tend to affect the peak power use. Items to verify would be: HVAC compressor efficiency, fan horsepower (defaulted when the HVAC system type was chosen), peak occupancy, peak lighting and equipment power densities, window shading coefficients, window shading devices, peak ventilation rate, and peak hot water usage in the building. It is essential that you examine "peak" values and *not* the duration of use in the 24-hour profiles. Profiles tend to affect energy consumption, while peak loads are only affected by the high points on the use profiles. Try modifying some peak values and re-running the software until the monthly differences are 20% or less and the annual is within 10% of the actual records.

Do not expect a perfect match to occur, since the computer model will be utilizing a long term 30-year "average" weather pattern, and your utility records are selected from a specific year. The weather driving the computer model will definitely be different from the year for which the building records are derived. It would be almost impossible to have a perfect match to *monthly* utility records.

---

b) Annual energy use in the disaggregation categories. 3B.2

Compare *the annual energy use by building system* (heating, cooling, fans, lighting, receptacles, and hot water) to the corresponding values derived from the disaggregation efforts done earlier. This will normally entail checking the KWH of electrical use and the CCF or MCF of gas use. In commercial buildings, however, you may find the only energy source is electricity, in which case the only energy use is in KWH.

If the results do not compare to within 20% of each other, check for the possible sources of the discrepancies. Keep notes on which categories match and which have discrepancies. Potential sources of error are misrepresentations of schedules for: lighting and receptacle, occupancy, ventilation, and hot water. Do not alter the peak values in this stage, because these were presumable already calibrated in step (a). Instead,

focus on the use schedules and durations. Correct if necessary and re-run the program to bring the disaggregated energy to within 20% and the total annual energy to within 10% of the actual utility records.

c) Annual energy costs for electricity and gas. 3B.1

If the energy peak and consumption are calibrated in steps (a) and (b), the energy costs predicted by the computer should also compare favorably to utility bills. If this does not happen, then check the rates entered into the computer program for electric energy ($/KWH), peak demand ($/KW) and for gas fuel ($ per therm) against the corresponding rates on the utility bills. Confirm that these are correct (in the Economics Data screen of ENER-WIN) and then execute the program again if necessary.

3C: RETROFIT STRATEGIES

After the simulation program has been adequately calibrated to the actual building's utility bill records, an in-depth study should be conducted on how to make the building more energy-efficient. First, it is important to see how "bad" the building's energy performance is with respect to accepted energy standards. Following that, we will identify the "problem areas" that account for the majority of the building's energy use. This will guide us into proposing retrofit strategies to improve the building's energy performance. Lastly, we will include a look at the building's life cycle cost to determine if the proposed retrofit designs are cost-effective.

a) Comparison to a standardized target performance.

We include in Appendix A and in the User's Manual a set of energy performance values known as B.E.P.S. (Building Energy Performance Standards). These were developed as target values and, in fact, have never been adopted as standards. Until such performance standards are developed, however, these will serve as useful energy targets for our purposes. The energy targets are expressed as "source line Btus per square foot per year". This means the total amount of resource energy consumed per gross square foot of conditioned building space. It is similar to an efficiency measurement we use for automobiles when we refer to "miles per gallon of gasoline." The B.E.P.S. values

are based on location (city) and building type. If your city is not listed, it is sufficient to simply use the city nearest to your location. The building type should be selected based on the building's major function — e.g., office, restaurant, secondary school, etc.

The simulation software prints out a value called the energy utilization factor for site line and source line. Read only the source line Btus per square foot, and compare this with the B.E.P.S. value. By doing this comparison, you will know how involved your efforts will be to try to bring the building's energy performance into alignment with the B.E.P.S. target. Sometimes a building's energy utilization will be as much as three times the B.E.P.S. value — meaning that there is a great deal of opportunity for improvements.

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b) Problem Identification.

Using the simulation output, it is a rather simple task to determine what the major energy users are in your building. Observe *the energy breakdowns* listed on the summary page and in the bar charts. These show the total energy (and cost) used in the categories of space heating, space cooling, fan energy, lighting, receptacles, and water heating. From this, you will know which area has the most room for improvement.

For heating and cooling, the information is further subdivided into annual loads caused by certain building components — i.e., roof, walls, windows solar, windows conducted, people, lights, ventilation and infiltration. The percentage contribution from each category is also shown, so again there is an immediate way to observe the major problem areas.

---

c) Energy Improvements through Retrofit Design Strategies.

After the problem areas have been identified, it is now up to the designer to differentiate between those areas that might have practical solutions to the energy problems and those that are not practical — e.g., some items (such as window shading or lighting fixtures) might be changed easily while other items (such as occupants) cannot be changed at all. It is useful to evaluate retrofit design strategies in three separate categories — (a) changes to operations, (b) physical changes to the building, and (c) changes to equipment.

First, select the changes that you think will be the lowest cost. Some of these may only require simple operational adjustments — like observing that the ventilation fans have been operating all night when

they are not needed and making a decision to reset on-off clocks or rescheduling the lighting system operation. These simple changes might save an impressive amount of energy.

After you have adjusted all the obvious low- or no-cost items, then consider changes to the equipment or the building features. This is the moment at which the designer's architectural knowledge will be the most valuable. It will be necessary to determine what sort of new design strategies will be the most practical and the most acceptable to apply to the building. Complex building changes that could alter the building's architectural appearance may require in-depth evaluation and sketching — like the addition of eyebrows to shade the windows from the sun. Each retrofit proposal must be considered from its visual acceptability and cost viewpoints. Costs should be derived as accurately as possible so the actual payback benefits from energy savings can be determined in a meaningful manner.

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d) Life-Cycle Costing

Frequently retrofit decisions are based on economic evaluations in addition to or instead of energy savings evaluations. At the end of the simulation output is a table that expresses the project's life-cycle cost in terms of *Present Worth*. This is a useful comparison tool if care has been taken to input appropriate economic parameters and accurate costs of new retrofit investments when the program is executed. The program will automatically adjust the present worth of annual operating costs based on the energy costs that result from each design scenario entered. The user, however, must be aware that many changes are not free of first cost, and these costs must be entered with each new design proposal.

For example, extending roof overhangs will usually result in lower air conditioning costs (and thus the present worth of operating costs), but the user must remember to add the roof overhang cost to the building's overall "square foot cost" when the project is entered.

Though the program only performs the present worth model, several alternative economic comparison techniques can be employed by the designer to evaluate the cost-effectiveness of various retrofit strategies. The user might choose to do a "payback" analyses by manually extracting only the annual costs (or savings) from the run and entering these into an investment payback equation. Most techniques will still utilize the economic life and various interest rates and discount rates. These should be decided before the first base case run is executed and then held constant throughout all the subsequent retrofit runs.

3D: FINAL REPORT

After you have completed the above processes, write the final report that include the followings:

a) Building Data

These include the project information, the weather condtions, the economic parameters, the building geometry, zoning, building materials, HVAC, lighting and water heating systems, operating schedules, and explanations of the building surroundings. Also include the actual monthly utility records of the building.

b) Simulation and Calibration

Explain the simulation and the calibration processes that you have made. Explain the inputs that you calibrated in order to match the actual data,

c) Existing Problems

This includes the current energy problems in the building based on the results of your calibrated computer simulation. Use pie chart(s) or any kind of graphical presentations.

d) Retrofit Designs

This includes all alternatives for building retrofit designs that you have studied. Also include the explanations of the most energy-efficient designs. Use graphics to present your results.

e) Reference Materials

Describe all reference materials that you use to describe the building (especially the thermal properties of the envelope assemblies). Also include all references that you use to analyze the problems and propose the retrofit designs.

VITAL SIGNS

SUMMARY CHECKLIST

ACTIVITY	ITEMS	METHODS	EQUIPMENT
LEVEL 1: Determining Candidacy for full work-up	Select a building based on: • Building type • Floor area • Number of floors	Assigned by instructor, or selected by the student.	
a. Brief visit to obtain general information.	• Building name • Building description • Location (City & State) • Year of construction • Total floor area • Total occupants, occupancy profiles	• Interview the bldg. manager • Brief observation	
b. Obtain building physical data.	• Floor plan • Sections and elevations • Envelope assembly properties • Outside surroundings	If drawings are not available measure and/or estimate the building floor area, elevations, height, etc. Observe and record the envelope materials.	• camera • tape measures • heavy cord • helium balloon • compass
c. Obtain utility bill records and costs of fuel.	• Building's utility records for 1 year (electricity and gas) • Utility rate schedule	Interview: • Utility Company • Building manager.	
d. Quick calculation of energy use.	Calculate the total energy use per square-foot of floor area.	Use the utility bill records and divide with the total floor area. Compare with standards.	

ACTIVITY	ITEMS	METHODS	EQUIPMENT
LEVEL 2: Preparing the project for energy modeling			
a. Obtain Economics data	• Economic life of building and mechanical systems • Fuel costs and escalation rates • Discount rate • Demand charge	• Interview building manager	
b. Obtain building details, thermal properties, and outside features.	**Building Geometry:** • unique features related to energy conscious design • necessary details, e.g. overhangs, lightshelf, basement, insulation, roof and ceilings.	• Observe and record all details.	• electronic tape measures • manual tape measures • camera
	Thermal properties of envelope's materials: • Window thermal properties: U-value, Shading Coefficient, daylight transmissivity, emissivity • Wall and roof thermal properties: U-value, solar absorptivity, time lag, decrement factor.	• Record the wall/window details, estimate the thermal properties. Compare estimation to reference books.	• Footcandle meter for estimating daylight transmissivity of window glass.
	Outside: • Ground reflectance • Adjacent buildings, trees that shade the building.	• Observations	• Camera

ACTIVITY	ITEMS	METHODS	EQUIPMENT
c. Obtaining operating schedules and building systems.	**Schedules:** • Occupancy • Hot water • Ventilation • Lighting and receptacles	Interview, observation.	
	Temperature settings: • Summer occupied, winter occupied, summer unoccupied, and winter unoccupied.	Interview, temperature measurements.	Room thermometer.
d. Obtain detailed data for each building zone.	**General zone data:** • Zone floor area • Internal mass • Infiltration rate • Number of people	Observation.	
	HVAC systems: • Cooling and heating systems • Ventilation rate • List of central plant, Air Handling Unit, terminals	Interview, observation.	
	Lighting systems: • Lighting types and loads • Daylighting control, dimmer, sensor, if presents.	Interview, observation.	Footcandle meter, tape measures, reference books on lighting.
e. Disaggregation of actual energy use.	Disaggregate the total energy use into fan, lighting, receptacles, hot water, space cooling, and space heating energy.	See detailed methods.	

ACTIVITY	ITEMS	METHODS	EQUIPMENT
LEVEL 3: Simulating, Calibrating, and Retrofitting			
a. Run energy simulation program.	• Confirm the data once again • Input data to energy simulation program • Run the simulation		• Intel PC 386/above with Windows operating system. • ENER-WIN simulation program. • ENER-WIN User's Manual.
b. Calibrate the energy simulation model.	• Calibrate the monthly peak demands. • Calibrate the monthly and annual energy use.	• Compare the simulation results with disaggregated values and the total from the utility bill records. • Correct the input of the energy simulation model and re-run the simulation.	
c. Analyze and study the energy savings strategies.	• Compare the calibrated results with a reference/ target building • Analyze the problems • Propose energy saving strategies • Conduct optimization of strategies.	• Compare with standards (e.g. B.E.P.S.) • See tabular results of ENER-WIN. • Correct the problems and re-run the simulation • Compare results from retrofits with the current energy use. Compare the Present Worth of total cost.	References: • ASHRAE • Means Cost Data • Other references as listed in the Bibliography.
d. Write a report.	• All project information • Description of energy analysis procedure • Existing problems related to energy use (findings) • Suggestions/recommendations of retrofit designs • Reference materials used for project.		

Form 1A.1

PROJECT INFORMATION
Field Preparation

PROJECT INFORMATION
Use this form to collect and document general data of your building.

YOUR NAME	YOUR NAME	YOUR NAME
PROJECT NAME		BUILDING TYPE
PROJECT DESCRIPTION		
PROJECT LOCATION		STATE ZIP
YEAR OF CONSTRUCTION	TOTAL FLOOR AREA (SQ.FT.)	CONSTRUCTION COST ($/SQ.FT.))
TOTAL OCCUPIED DAYS/WEEK	ANNUAL HOLIDAYS (DAYS)	CIRCLE MONTHS WHEN VACANT 1 2 3 4 5 6 7 8 9 10 11 12

CASE STUDY BUILDING
Sketch your building or attach the photograph of your case study building.

CONTACTS
Place your principal contacts and their telephone numbers here.

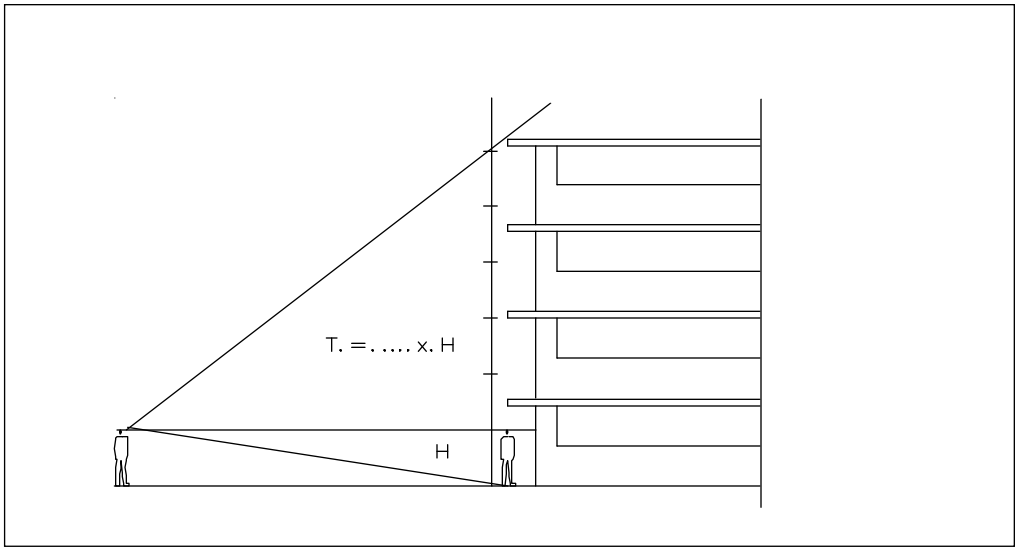
BUILDING OPERATOR		TELEPHONE
ARCHITECT		TELEPHONE
MECHANICAL ENGINEER		TELEPHONE
ENERGY CONSULTANT		TELEPHONE

Form 1B.1

METHODS FOR ESTIMATING BUILDING HEIGHT
Field Preparation

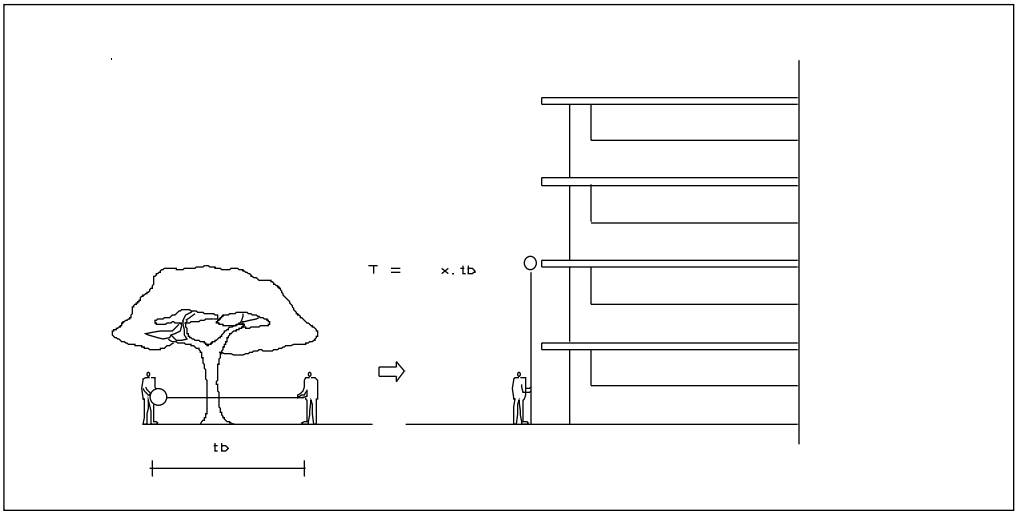
The following figures show two methods to estimate the building's height when drawings are not available. You need at least two people to do either of these methods and a stick or a helium balloon.

METHOD I
Ask a person, whose height is known, to stand closely to the building. Or use a stick with a known length, and put it close the building. Estimate the building's height by determining multiples of the height ot that person or the stick.



METHOD II
Use a helium balloon and tie it to a long cord. Hold the cord and let the balloon go up straight until it reaches the point where the balloon is at the same height as the building. Put a mark on the cord at the point where it touches the ground. Pull the balloon down and measure the distance between the balloon and the mark on the cord.

This method is practical for heights up to 50 feet. At higher levels, wind may become a problem.

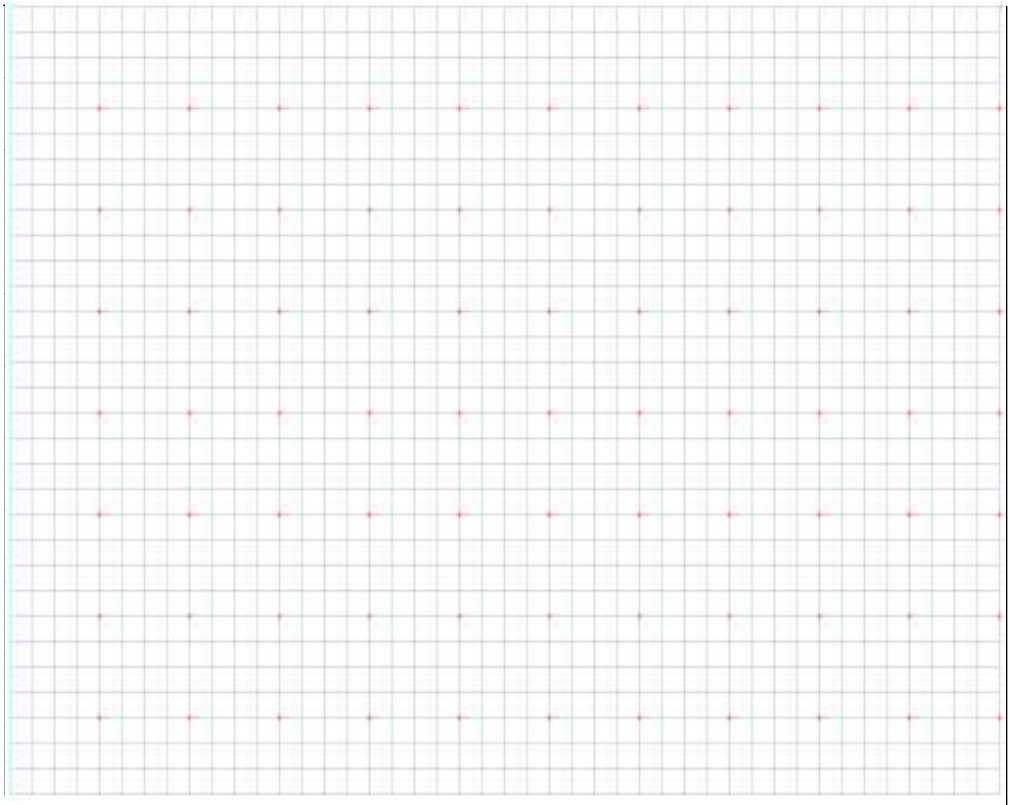


Form 1B.2

BUILDING SKETCH
Showing HVAC Zones

BUILDING SKETCH
Use this grids to sketch the floor plan of your building. Copy this sheet if you have more than one floor, and sketch each different floor plan on a separate sheet.

Sketch the floor plan according to the HVAC zones. You do not have to sketch the floor plan exactly the same as drawn in the architectural/shop drawing of this building.



NOTATIONS
Write the scale or grid size of your sketch. Also write the building orientation (in degrees from North), total building area, floor area of this plan, the level number, average ceiling height, and the number of floors typical of this floor plan.

SCALE / GRID SIZE (FEET PER GRID)				TOTAL BUILDING AREA
BLDG. ORIENTATION (FROM NORTH)				AVE. CEILING HEIGHT (FEET)
LEVEL NUMBER		FLOOR AREA OF THIS PLAN (FT2)		NO. OF FLOORS TYPICAL OF THIS PLAN
NOTES				

If the building has more than one typical floor,
COPY THIS SHEET TO SKETCH DIFFERENT FLOOR PLANS

Form 1C.1

UTILITY BILL RECORDS

UTILITY BILL RECORDS
Using the monthly utility records of your building, write the following values for each month: KWH electric use, KW peak, Electric Energy Charge, Electric Peak Demand Charge, and Therms of gas and cost of gas if the building uses gas for heating.

(a) MONTH	(b) KWH ELECTRIC	(c) KW PEAK	(d) ELECTRIC ENEGY CHARGE	(e) ELECTRIC PEAK DEMAND CHARGE	(f) THERMS OF GAS USED	(g) COST OF GAS
TOTALS						
			(d)/(b) =	**(e)/(c) =**		**(g)/(f) =**

COST PER UNIT
Divide total annual cost by consumption to get the cost per unit.

ENERGY UTILIZATION FACTOR
Calculate the Energy Utilization Factor (EUF) and then compare the result with B.E.P.S. (Appendix A).

$$\text{EUF} = \frac{\text{\_\_\_\_\_ Kwh x 10,500 + \_\_\_\_\_ Therms x 100,000}}{\text{\_\_\_\_\_ sq.ft. x 1,000}}$$

EUF = _____ **MBtu/sq.ft.** **B.E.P.S. =** _____ **MBtu/sq.ft.**

Form 2A.1

ECONOMICS DATA

ECONOMICS DATA
Use this form to collect and document the economics data of your case study building.

BUILDING ECONOMIC LIFE (YEARS)		MECHANICAL SYSTEM LIFE (YEARS)	
DISCOUNT RATE		BUILDING COST ESCALATION RATE	
ELECTRIC COST ($/KWH)		ELECTRIC COST ESCALATION RATE	
GAS COST ($/THERM)		GAS COST ESCALATION RATE	
WATER COST ($/1000 GALLON)		WATER COST ESCALATION RATE	

DEMAND CHARGE RATE STRUCTURE	
KW	**$/KW**

CONTACTS
Place the utility company name, contact persons and their telephone numbers here.

UTILITY COMPANY (ELECTRIC)		ADDRESS	
		CONTACT PERSON	TELEPHONE
UTILITY COMPANY (GAS)		ADDRESS	
		CONTACT PERSON	TELEPHONE
UTILITY COMPANY (WATER)		ADDRESS	
		CONTACT PERSON	TELEPHONE

Form 2B.1

THERMAL PROPERTIES OF THE ENVELOPE

WALL AND ROOF PROPERTIES
By analyzing the material assemblies, try to estimate the properties of the walls and roofs: U-Factor, Solar Absorptivity, Time Lag, Decrement Factor, and Installed Cost.

You can also use the data from literature listed in the Annotated Bibliography.

If you do not know the decrement factor, just enter 0 (zero).

WALL AND ROOF PROPERTIES

NO.	DESCRIPTION	U-FACTOR	SOLAR ABSORPTIVITY	TIME LAG (HRS.)	DECREMENT FACTOR	INSTALLED COST ($/SQ.FT.)

WINDOW AND SKYLIGHT PROPERTIES
By analyzing the glazing assemblies, try to estimate the properties of the windows and skylights: U-Factor, Solar Heat Gain Factor, Emissivity, Daylight Transmissivity, and Installed Cost.

You can also use the data from literature listed in the Annotated Bibliography.

WINDOW AND SKYLIGHT PROPERTIES

NO.	DESCRIPTION	U-FACTOR	SOLAR HEAT GAIN FACTOR	EMISSIVITY	DAYLIGHT TRANSMISSIVITY	INSTALLED COST ($/SQ.FT.)

Form 2C.1

OPERATING SCHEDULES

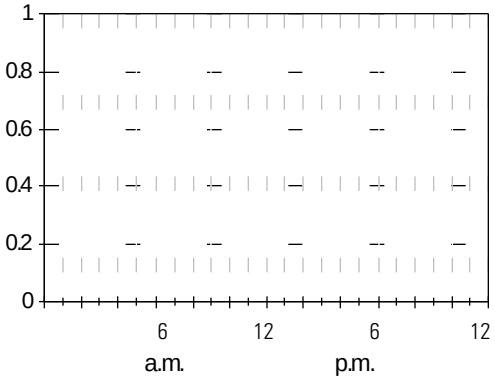
OCCUPANCY PROFILES
Sketch the 24-hour profile of the occupancy in decimal fractions of the value when the occupancy is at the peak. For example, if the building is fully-occupied, the value is 1 (for 100 percent). If the building is half-occipied, the value is 0.5.

HOT WATER
Sketch the 24-hour profile of the hot water usage in decimal fractions of the peak hot water usage.

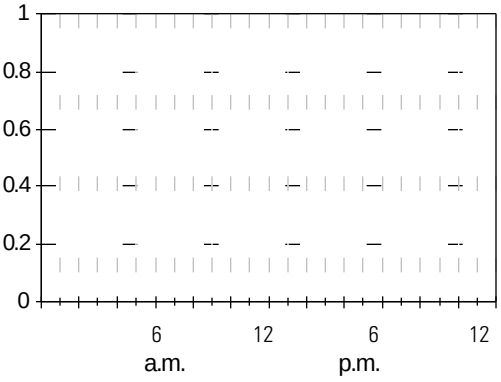
VENTILATION
Sketch the 24-hour profile of the ventilation in decimal fractions of the value when the ventilation is at the peak. However, usually the value is either 0 or 1. 0 means the fan is off and 1 means the fan is on.

LIGHTING
Sketch the 24-hour profile of the lighting in decimal fractions of the value when the lighting load is at the peak.

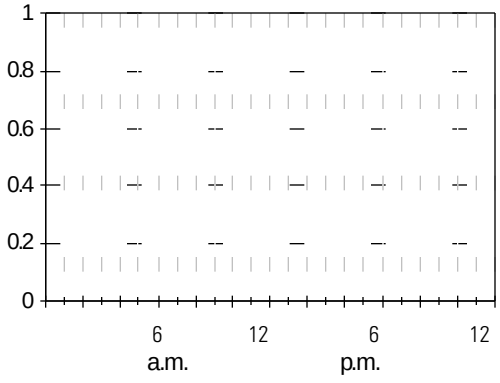
OCCUPANCY No. ____



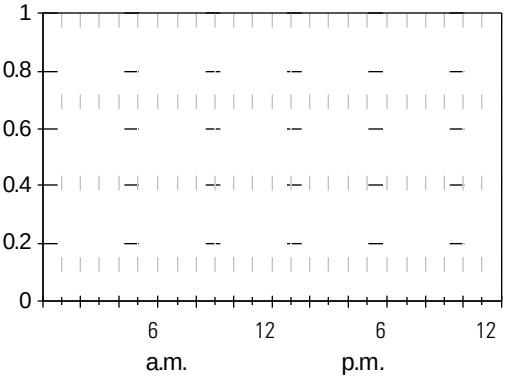
HOT WATER No. ____



VENTILATION No. ____



LIGHTING No. ____



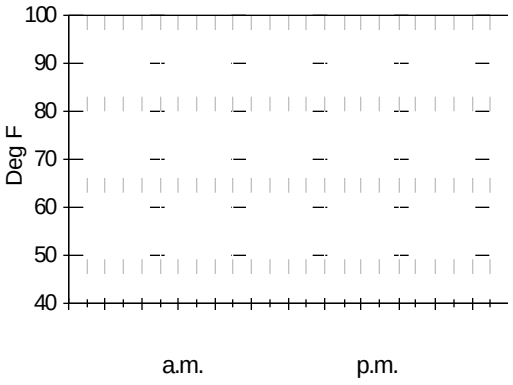
COPY THIS SHEET IF NECESSARY

Form 2C.2

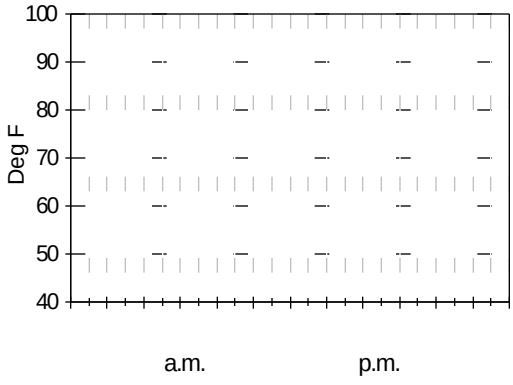
TEMPERATURE SETTINGS

TEMPERATURE SETTINGS
Sketch the 24-hour temperature settings in degrees Fahrenheit (they are the actual temperature settings and not in decimal fractions). Sketch the profiles for four different conditions: summer occupied, winter occupied, summer unoccupied, and winter unoccupied.

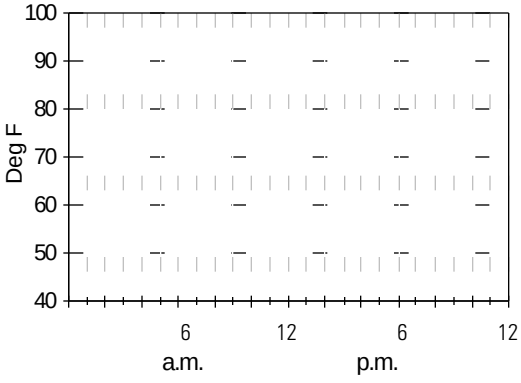
SUMMER UNOCCUPIED No. ____



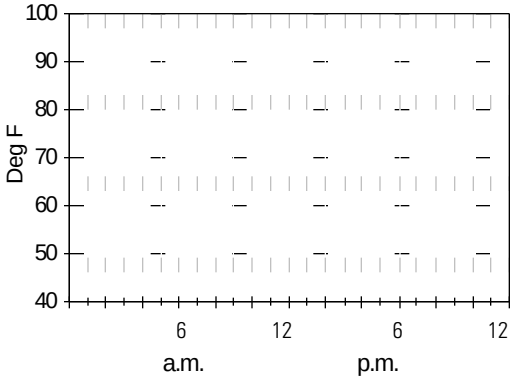
WINTER UNOCCUPIED No. ____



SUMMER UNOCCUPIED No. ____



WINTER UNOCCUPIED No. ____



COPY THIS SHEET IF NECESSARY

Form 2D.1

ZONE DESCRIPTIONS
(Copy this sheet for each zone)

GENERAL ZONE DATA Record the general data only for this zone.	ZONE NO.	ZONE NAME			
	ZONE AREA (SQ.FT.)	INTERNAL MASS (PSF)	INFILTRATION RATE (ACH)		
LOADS, PROFILES, AND TEMPERATURE SETTINGS Record the loads and profiles of the occupancy, hot water, ventilation and lighting. Also record the temperature settings.	NO. OF OCCUPANTS	HOT WATER (GALLON/ PERSON/DAY)	VENTILATION (CFM/ PERSON)	LIGHTING (WATT/ SQ.FT.)	EQUIP. (WATT/ SQ.FT.)
	OCCUPANCY PROF. NO.	HOT WATER PROF. NO.	VENTILATION PROF. NO.	LIGHTING & EQUIP. PROF. NO.	
	SUMMER OCCUPIED TEMP. SETTING NO.	WINTER OCCUPIED TEMP. SETTING NO.	SUMMER UNOCCUPIED TEMP. SETTING NO.	WINTER UNOCCUPIED TEMP. SETTING NO.	
HVAC SYSTEMS Record the data of the HVAC systems.	ECONOMIZER CYCLE (Y/N)	NATURAL VENTILATION (Y/N)	NATURAL VENTILATION RATE (CFM/SQ.FT.)		
	AC TYPE	COOLING SEER	HEATING TYPE	HEATING COP	
	HVAC FIRST COST ($/TON)	MAINTENANCE COST ($/TON/YEAR)			
LIGHTING SYSTEMS Record the lighting systems.	LIGHTING TYPE	LIGHTING COST ($/SQ.FT.)	ZONE DEPTH FOR DAYLIGHTING	TARGET LIGHTING LEVEL (FOOTCANDLES)	

ZONE SKETCH
Sketch this zone only. Try to include all data on the sketch, such as: the wall and window material and areas, the type(s) of exterior ground surface and wall exposure, and any other necessary data if daylight is used:

SILL HEIGHT = _____ FT.

TOP OF WINDOW HEIGHT = _____ FT

GROUND REFLECTANCE = _____

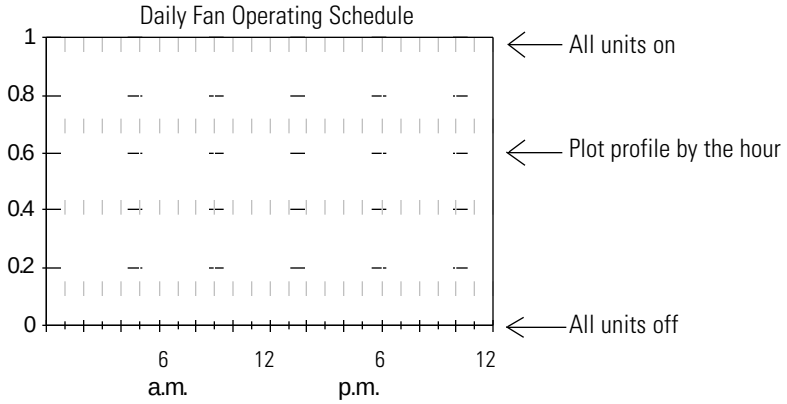
WINDOW SHADE TRANSMISSIVITY = _____

Form 2E.1

DISAGGREGATION OF ACTUAL ENERGY USE

(a) Fan Motors (QF):

FAN OPERATING SCHEDULE
Sketch the 24-hour operating schedule of the fan in decimal fraction of the peak fan motor usage.



FAN OPERATING ENERGY
Calculate the annual energy (in KWH/yr) for fan motors by filling the blanks.

Daily Operating Hours (DOH) = $\sum_{i=1}^{24}$ profile $_i$ = _____ hrs/day

Check one: F = 1 _____ Constant Volume Fans

F = 0.8 _____ Variable Volume Fans

Fan KW: KW max = 0.75 x _____ h.p. = _____ KW

or

KW max = _____ Volts x _____ Amps / 1000 = _____ KW

KW ave = $\frac{\text{_____}}{\text{KWmax}}$ x $\frac{\text{_____}}{\text{F}}$ = _____ KW

Fan Energy (QF):

KWH/day = $\frac{\text{_____}}{\text{KWave}}$ x $\frac{\text{_____}}{\text{DOH}}$ = _____ KWH / day

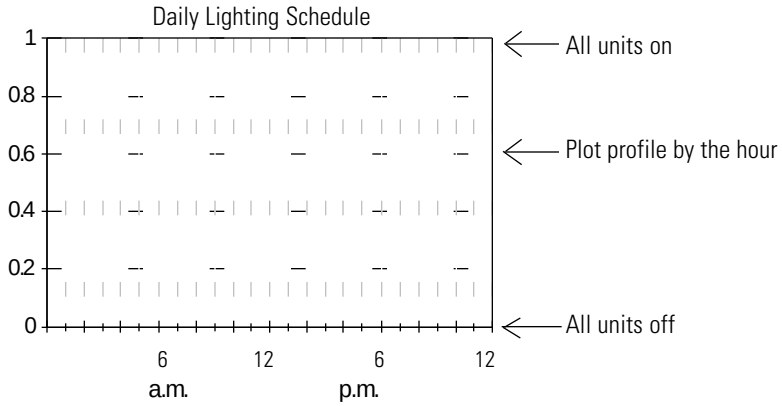
QF = $\frac{\text{_____}}{\text{KWH/day}}$ x $\frac{\text{_____}}{\text{occ.days/yr.}}$ = _____ KWH / yr.

Form 2E.2

DISAGGREGATION OF ACTUAL ENERGY USE (Cont'd..)

(b) Lighting (QL):

LIGHTING SCHEDULE
Sketch the 24-hour operating schedule of the lights in decimal fraction of the peak lighting usage.



LIGHTING ENERGY
Calculate the annual energy (in KWH/yr) for lighting by filling the blanks.

Daily Lighting Hours (DLH) = $\sum_{i=1}^{24}$ profile = _____ hrs

Check one: F = 1 _____ Incandescent Lights

F = 1.25 _____ Fluorescent Lights

Peak KW: KW max = _____ (F) x _____ (watts/lamp) x _____ (no. of lamps) / 1000 = _____ KW

Lighting Energy (QL):

KWH/day = _____ (KWmax) x _____ (DLH) = _____ KWH

QL = _____ (KWH/day) x _____ (occ.days/wk) x _____ (weeks/yr.) = _____ KWH / yr.

Form 2E.3

DISAGGREGATION OF ACTUAL ENERGY USE (Cont'd..)

RECEPTACLE ENERGY
Calculate the annual energy (in KWH/yr) for receptacles by filling the blanks.

(c) Receptacles (QE):

Total Receptacle Watts (EW) = _____ Watts

Power Density (PD) = _____ / _____ = _____ W/sq.ft.
EW Bldg. Area (sq.ft.)

Receptacle KW = _____ / 1000 = _____ KW
EW

KWH / day = _____ x _____ = _____ KWH / day
Equip. KW DLH

Receptacle Energy (QE):

QE = _____ x _____ x _____ = _____ KWH / yr.
KWH/day occ.days/wk weeks/yr.

WATER HEATING ENERGY
Calculate the annual energy (in Btus or KWH/yr) for water heating by filling the blanks.

(d) Water Heating (QWH):

QD = _____ x _____ x 8.33 x (140 - _____) x _____
Occupants Gal/day/person Ground Temp. occ.days/yr.

= _____ Btus / yr.

Water Heating Energy (QWH):

QWH gas = _____ / _____ = _____ Btus
QD Efficiency of Heater

or

QWH elec. = _____ / 3413 = _____ KWH / yr.
QD

Form 2E.4

DISAGGREGATION OF ACTUAL ENERGY USE (Cont'd..)

SPACE COOLING ENERGY
Calculate the annual energy (in KWH/yr) for cooling by filling the blanks. Notice that the calculation for gas-heated building is different than for electrically-heated building.

(e) Space Cooling (QC):

- Gas Heated Building.

QC = _____ - _____ - _____ - _____ - _____
Total annual KWH; QF (fans); QL (lights); QE (receptacles); QWH elec. (hot water)

= _____ KWH / yr.

- Electrically Heated Building.

Monthly KWH for fans + lights + receptacles + hot water =

QM = (_____ + _____ + _____ + _____) / 12 = _____ KWH /month
QF QL QE QWH elec.

Neutral Months, Balance Temperature Range (tb) = 40 - 50 deg. F

AVERAGE MONTHLY TEMPERATURES
Fill the blanks below with the average monthly temperatures. Use these to help determine the neutral months.

MONTH	AVE. TEMP.
Jan.	_____
Feb.	_____
Mar.	_____
Apr.	_____
May	_____
Jun.	_____
Jul.	_____
Aug.	_____
Sep.	_____
Oct.	_____
Nov.	_____
Dec.	_____

	NAME OF MONTH	TOTAL ELEC.	ELEC. USED FOR a, b, c, d (QM)	ELEC. FOR HEATING & COOLING	ELEC. FOR COOLING (KWH)
Neutral Months	_____	_____	- _____ =	_____ x 1/2 =	_____
	_____	_____	- _____ =	_____ x 1/2 =	_____
Other Months > tb	_____	_____	- _____ =		_____
	_____	_____	- _____ =		_____
	_____	_____	- _____ =		_____
	_____	_____	- _____ =		_____
	_____	_____	- _____ =		_____
					_____ +

QC elec. Total = _____KWH/yr

Form 2E.5

DISAGGREGATION OF ACTUAL ENERGY USE (Cont'd..)

SPACE HEATING ENERGY
Calculate the annual energy (in KWH/yr) for space heating by filling the blanks. Notice that the calculation for gas heated building is different than for electrically-heated building.

(f) Space Heating (QH):

- Gas Heated Building.

QH gas = _____ - _____
Total annual gas Btus — QWH gas

= _____ Btus

- Electrically Heated Building.

Monthly KWH for fans + lights + receptacles + hot water =

QM = (_____ + _____ + _____ + _____) / 12 = _____ KWH /month
QF QL QE QWH

AVERAGE MONTHLY TEMPERATURES
See Form 2E.4 for average monthly temperatures.

Neutral Months, tb = 40 - 50 deg. F

	NAME OF MONTH	TOTAL ELEC.		ELEC. USED FOR a, b, c, d (QM)		ELEC. FOR HEATING & COOLING		ELEC. FOR HEATING (KWH)
Neutral Months	_____	_____	-	_____	=	_____	x 1/2 =	_____
	_____	_____	-	_____	=	_____	x 1/2 =	_____
Other Months < tb	_____	_____	-	_____	=			_____
	_____	_____	-	_____	=			_____
	_____	_____	-	_____	=			_____
	_____	_____	-	_____	=			_____
	_____	_____	-	_____	=			_____
								_____ +

QH elec. Total = _____KWH/yr.

Form 2E.6

DISAGGREGATION OF ACTUAL ENERGY USE (Cont'd..)

ENERGY SUMMARIES
Write the energy used for each category: fan motors, lighting, receptacles, water heating, space cooling, and space heating.

Multiply all electricity KWH with 3,413 to obtain the **Site Btus.** Do not modify any of the gas Btus. Record gas Btus directly in the "Site Btus" column. Compute the total of all Site Btus and then compute the % in each category.

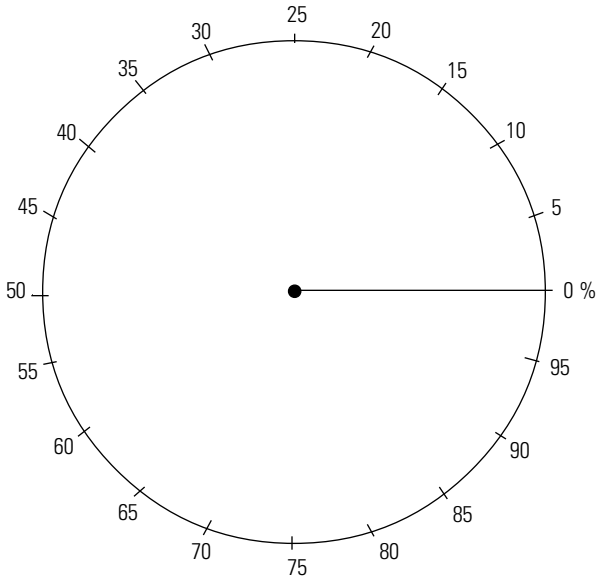
(g) Energy Summaries

CATEGORY		ELECTRIC KWH		SITE BTUS	% OF TOTAL
Fan Motors			x 3,413		
Lighting					
Receptacles					
Water Heating	Gas				
	Elec.				
Space Cooling					
Space Heating	Gas				
	Elec.				
TOTALS					100 %

Transfer these data to Form 3B.2

PIE CHART OF ENERGY USE
Make the pie chart that shows the energy used by each category. Simply draw lines to separate the category, and write the percentage inside the area of each category.

Pie Chart:



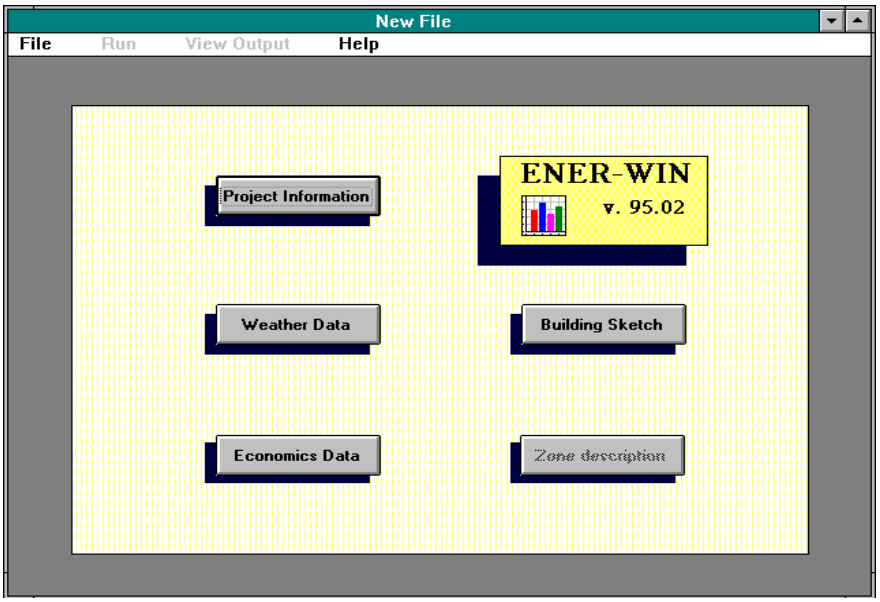
Form 3A.1

COMPUTER SIMULATION
(Samples of ENER-WIN Screens)

ENER-WIN MAIN MENU

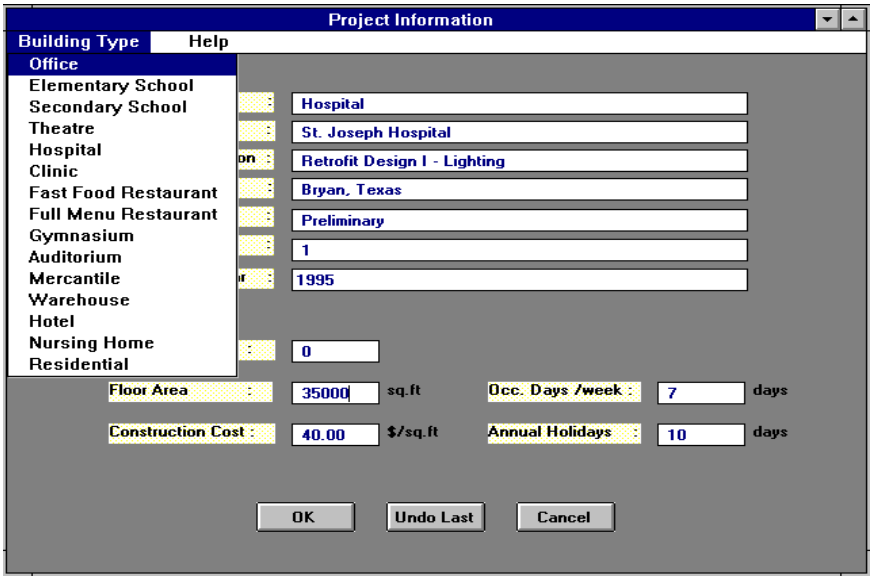
The main menu of ENER-WIN consists of two types of menus: (1) Pull-down, and (2) Command-button. The pull-down menu consists of (a) File: to open a new project and retrieve an exisiting project, to save a project file, (b) Run: to run the energy simulation, (c) View Output: to view the simulation output, and (d) Help: to get On-line Help.

The Command-button menu consists of (a) Project Information: to enter general project data, (b) Weather Data: to select weather data from the database, (c) Economics Data: to enter economics parameters, (d) Building Sketch: to sketch the building HVAC zones, and (e) Zone Description: to enter detailed data of each building zone.



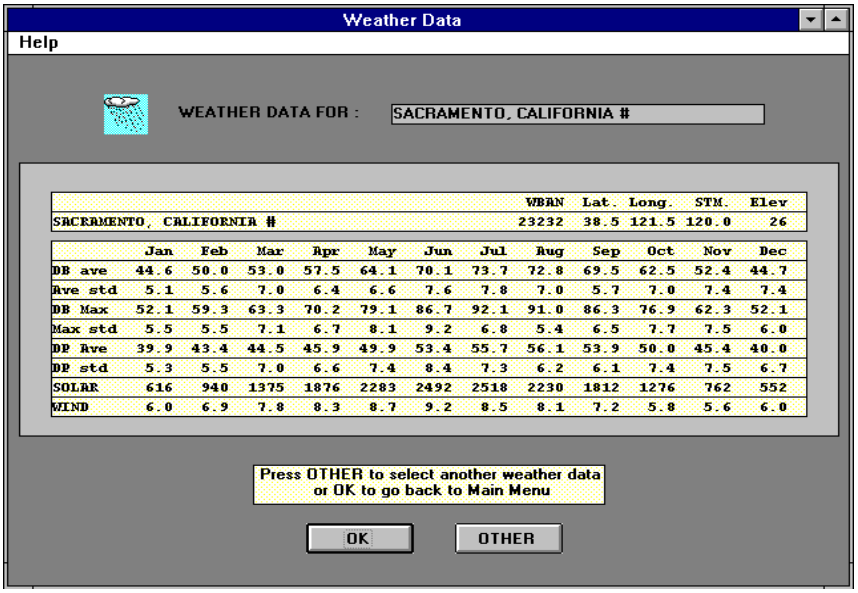
PROJECT INFORMATION

This is the screen where you enter general information about the building. For a new project, select a building type from the Building Type pull-down menu. As soon as you select a building type, ENER-WIN will automatically install all default values related to that building type .



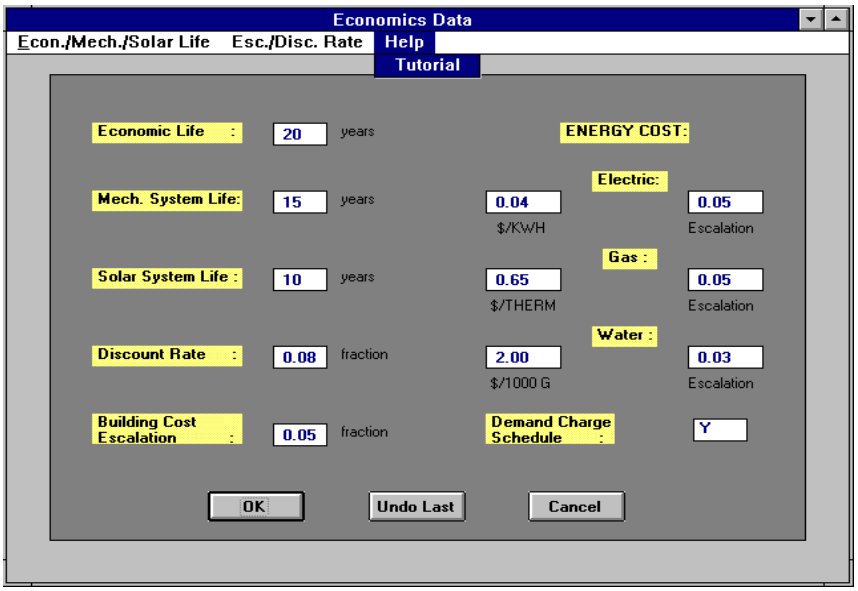
Form 3A.2

WEATHER DATA
The Weather Data screen of ENER-WIN presents the weather data of the city where your building is located. To select new weather data, click "Other" button on this screen. ENER-WIN is supported with a weather data base for 270 U.S. and foreign cities based on 30-year statistics.



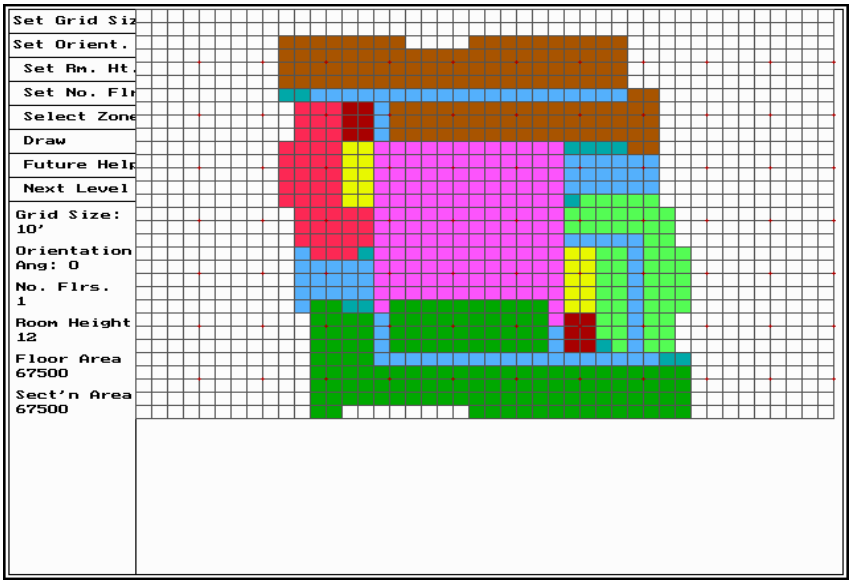
SACRAMENTO, CALIFORNIA #								WBAN 23232	Lat. 38.5	Long. 121.5	STM. 120.0	Elev 26
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
DB ave	44.6	50.0	53.0	57.5	64.1	70.1	73.7	72.8	69.5	62.5	52.4	44.7
Ave std	5.1	5.6	7.0	6.4	6.6	7.6	7.8	7.0	5.7	7.0	7.4	7.4
DB Max	52.1	59.3	63.3	70.2	79.1	86.7	92.1	91.0	86.3	76.9	62.3	52.1
Max std	5.5	5.5	7.1	6.7	8.1	9.2	6.8	5.4	6.5	7.7	7.5	6.0
DP Ave	39.9	43.4	44.5	45.9	49.9	53.4	55.7	56.1	53.9	50.0	45.4	40.0
DP std	5.3	5.5	7.0	6.6	7.4	8.4	7.3	6.2	6.1	7.4	7.5	6.7
SOLAR	616	940	1375	1876	2283	2492	2518	2230	1812	1276	762	552
WIND	6.0	6.9	7.8	8.3	8.7	9.2	8.5	8.1	7.2	5.8	5.6	6.0

ECONOMICS DATA
On this screen, you can enter the economic parameters of your building. These economic parameters will be used by ENER-WN to perform Life-Cycle Cost Analysis.

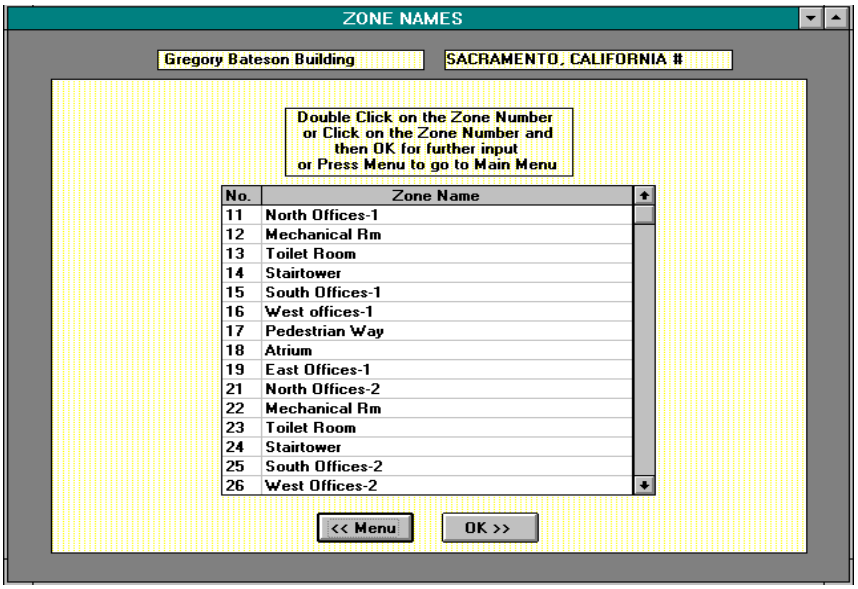


Form 3A.3

BUILDING SKETCH
To enter detailed data of the builidng, you need to sketch the building HVAC zones, indicated with different colors. You can specify the grid size, building orientation, ceiling height, and number of floors typical of this floor plan. On each level (floor plan), you can draw up to 10 HVAC zones.



ZONE LIST
This screen shows all zone names in your building. These zones are recorded automatically after you sketched the building HVAZ zones. Double click a zone name to enter all detailed data of that particular zone.

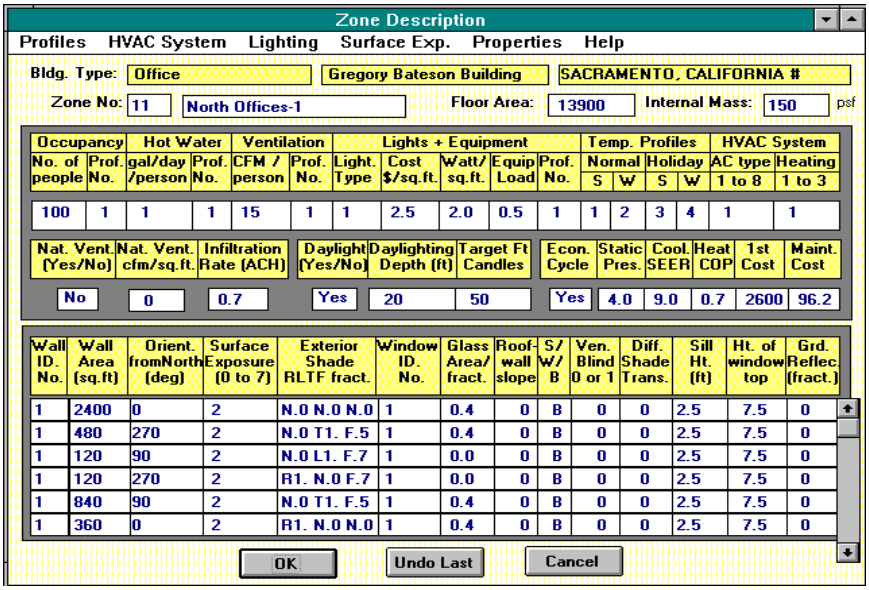


Form 3A.4

ZONE DESCRIPTION

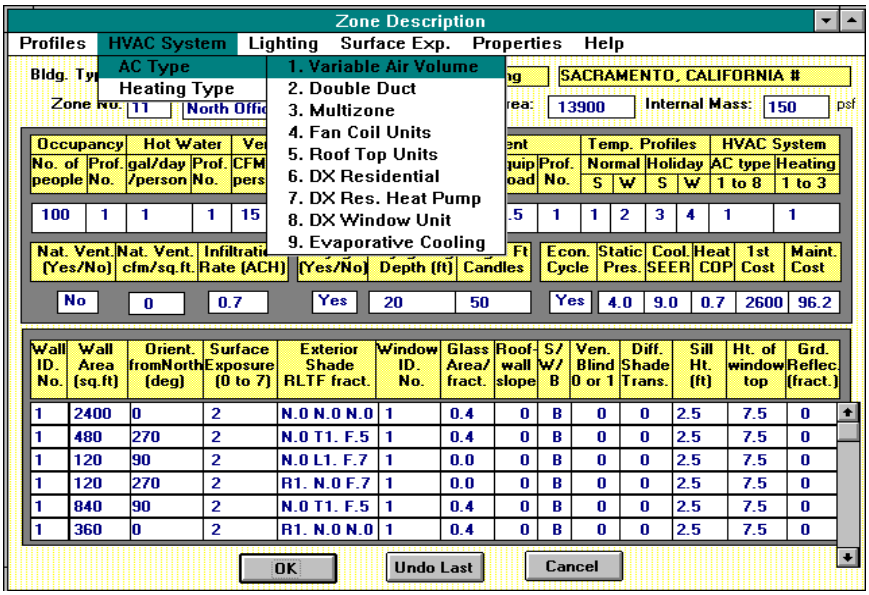
ENER-WIN will automatically install the default values after you selected a building type, and it will also install all geometrical data after you sketched the building. On this screen, you can edit these default values and specify other values, such as the data for daylighting.

This screen consists of several pull-down menus to enter the zone's profiles/settings, HVAC systems, lighting system, and thermal properties of the envelopes.


Zone Description
Profiles HVAC System Lighting Surface Exp. Properties Help
Bldg. Type: Office
Gregory Bateson Building
SACRAMENTO, CALIFORNIA #
Zone No: 11
North Offices-1
Floor Area: 13900
Internal Mass: 150
psf
Occupancy
Hot Water
Ventilation
Lights + Equipment
Temp. Profiles
HVAC System
No. of people
Prof. No.
gal/day /person
Prof. No.
CFM / person
Prof. No.
Light. Type
Cost $/sq.ft.
Watt/ sq.ft.
Equip Load
Prof. No.
Normal S W
Holiday S W
AC type
Heating
1 to 8
1 to 3
100 1 1 1 15 1 1 2.5 2.0 0.5 1 1 2 3 4 1 1
Nat. Vent. (Yes/No)
Nat. Vent. cfm/sq.ft.
Infiltration Rate (ACH)
Daylight (Yes/No)
Daylighting Depth (ft)
Target Ft Candles
Econ. Cycle
Static Pres.
Cool. SEER
Heat COP
1st Cost
Maint. Cost
No 0 0.7 Yes 20 50 Yes 4.0 9.0 0.7 2600 96.2
Wall ID. No.
Wall Area (sq.ft)
Orient. fromNorth (deg)
Surface Exposure (0 to 7)
Exterior Shade RLTF fract.
Window ID. No.
Glass Area/ fract.
Roof-wall slope
S/W/B
Ven. Blind 0 or 1
Diff. Shade Trans.
Sill Ht. (ft)
Ht. of window top
Grd. Reflec (fract.)
1 2400 0 2 N.0 N.0 N.0 1 0.4 0 B 0 0 2.5 7.5 0
1 480 270 2 N.0 T1. F.5 1 0.4 0 B 0 0 2.5 7.5 0
1 120 90 2 N.0 L1. F.7 1 0.0 0 B 0 0 2.5 7.5 0
1 120 270 2 R1. N.0 F.7 1 0.0 0 B 0 0 2.5 7.5 0
1 840 90 2 N.0 T1. F.5 1 0.4 0 B 0 0 2.5 7.5 0
1 360 0 2 R1. N.0 N.0 1 0.4 0 B 0 0 2.5 7.5 0
OK
Undo Last
Cancel

HVAC SELECTIONS

This figure shows the menu of the HVAC systems available in one of the "pull-downs".

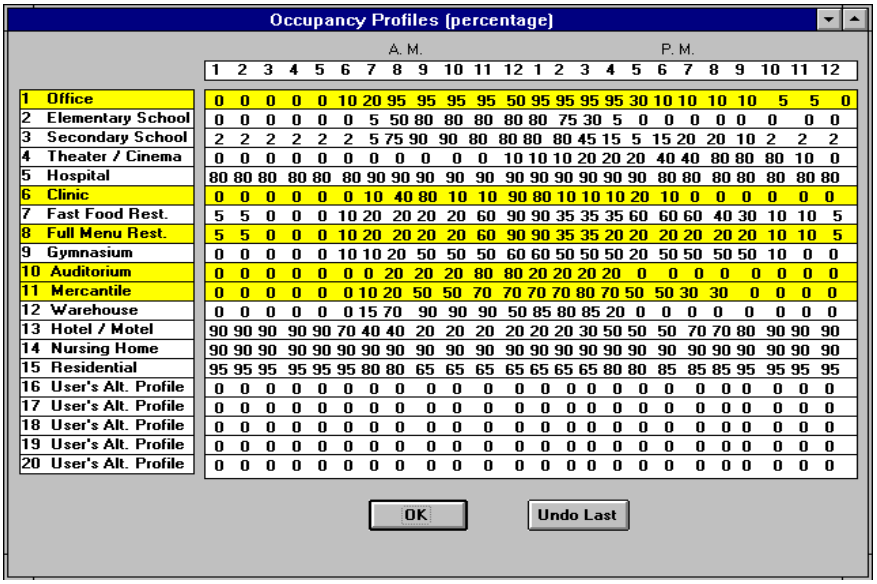


Form 3A.5

OCCUPANCY PROFILES

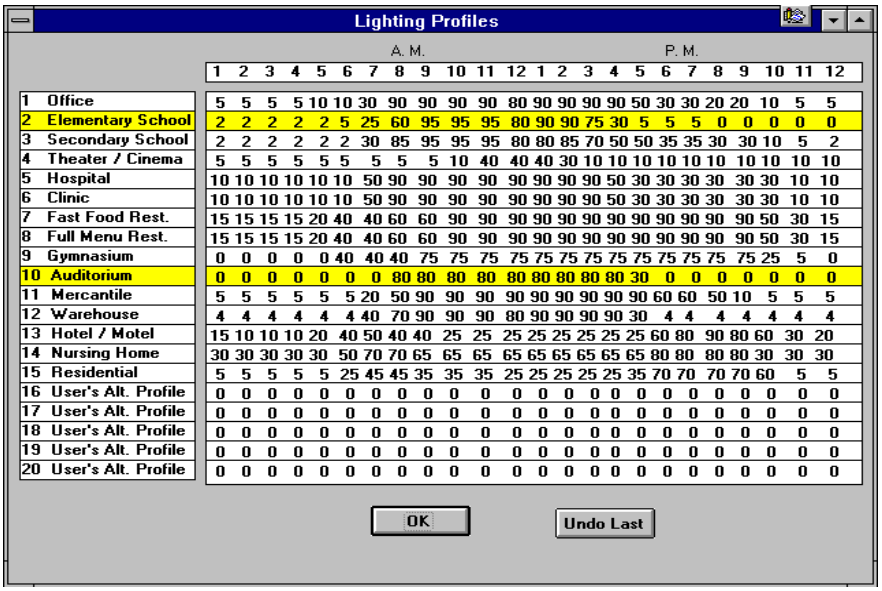
One of the profiles you need to specify is the Occupancy profile. Other profiles are ventilation, hot water, and lighting profiles. You also need to specify the temperature settings of each zone.

You can either select a default profile, edit the default values, or add a new profile.



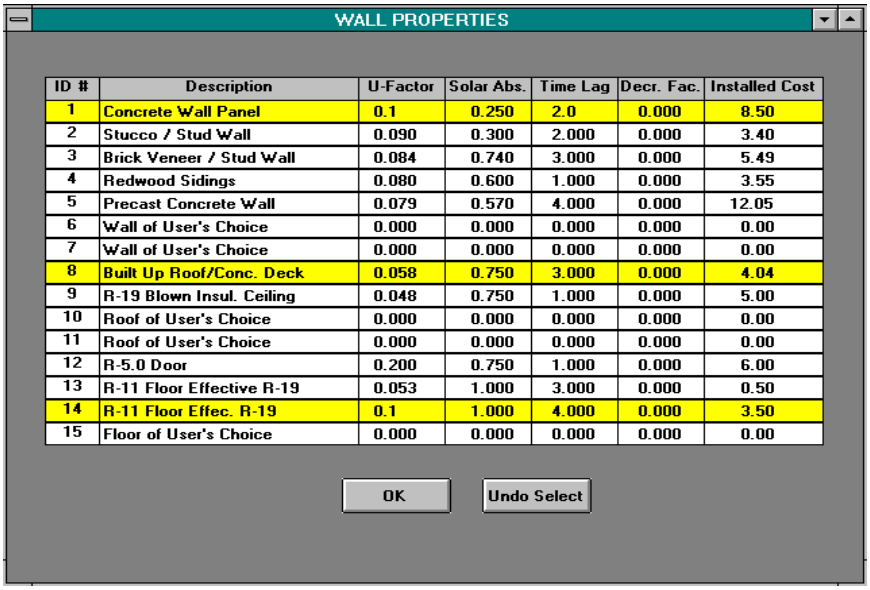
LIGHTING PROFILES

ENER-WIN will highlight a lighting profile based on the building type you selected. However, you can specify another profile for a particular zone and you can also edit the values that are set by ENER-WIN.



Form 3A.6

WALL & ROOF CATALOG
This is a catalog for the thermal properties of the walls and roofs. You can either select and accept the default value, edit the default values, or add new values. You can also specify the actual installed cost of the material assemblies.

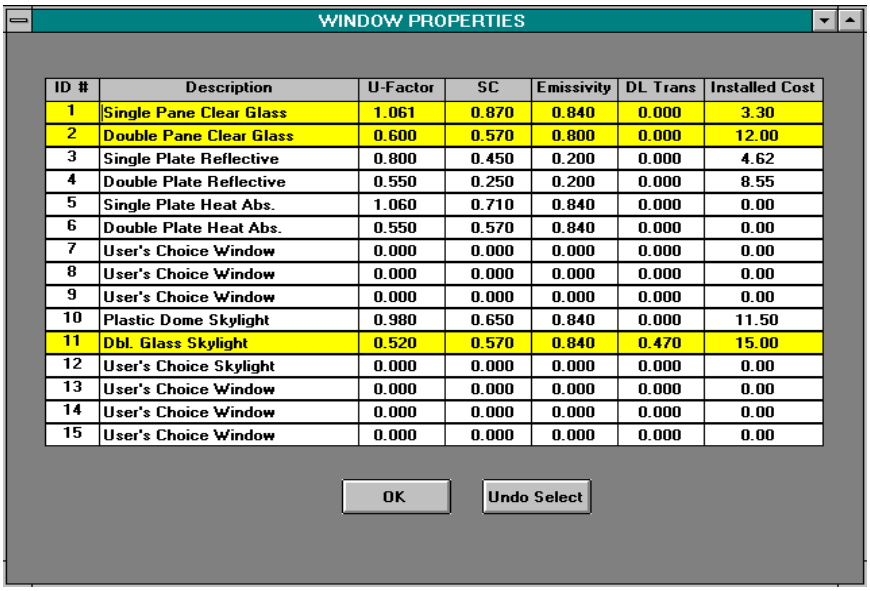


WALL PROPERTIES

ID #	Description	U-Factor	Solar Abs.	Time Lag	Decr. Fac.	Installed Cost
1	Concrete Wall Panel	0.1	0.250	2.0	0.000	8.50
2	Stucco / Stud Wall	0.090	0.300	2.000	0.000	3.40
3	Brick Veneer / Stud Wall	0.084	0.740	3.000	0.000	5.49
4	Redwood Sidings	0.080	0.600	1.000	0.000	3.55
5	Precast Concrete Wall	0.079	0.570	4.000	0.000	12.05
6	Wall of User's Choice	0.000	0.000	0.000	0.000	0.00
7	Wall of User's Choice	0.000	0.000	0.000	0.000	0.00
8	Built Up Roof/Conc. Deck	0.058	0.750	3.000	0.000	4.04
9	R-19 Blown Insul. Ceiling	0.048	0.750	1.000	0.000	5.00
10	Roof of User's Choice	0.000	0.000	0.000	0.000	0.00
11	Roof of User's Choice	0.000	0.000	0.000	0.000	0.00
12	R-5.0 Door	0.200	0.750	1.000	0.000	6.00
13	R-11 Floor Effective R-19	0.053	1.000	3.000	0.000	0.50
14	R-11 Floor Effec. R-19	0.1	1.000	4.000	0.000	3.50
15	Floor of User's Choice	0.000	0.000	0.000	0.000	0.00

OK Undo Select

WINDOW & SKYLIGHT CATALOG
This is a catalog for the thermal properties of the windows and skylights. You can either select and accept the default value, edit the default values, or add new values. You can also specify the actual installed cost of the windows or skylights.



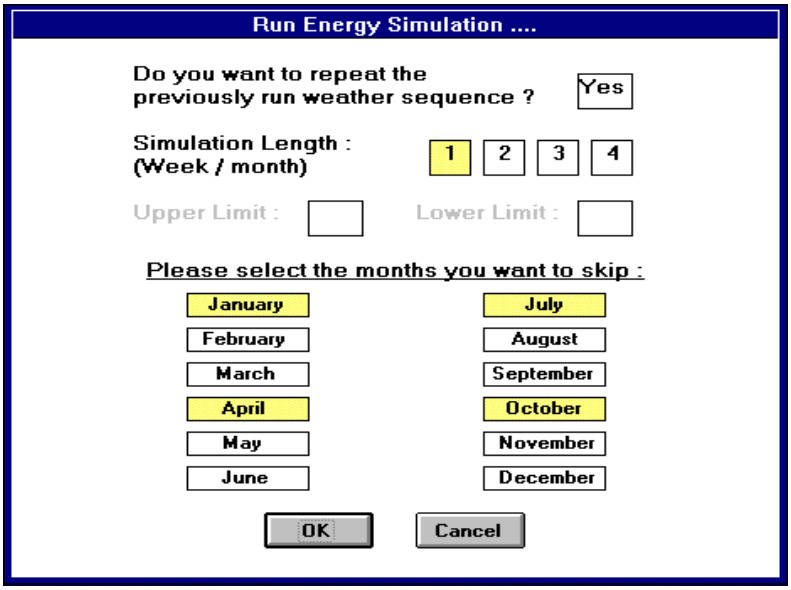
WINDOW PROPERTIES

ID #	Description	U-Factor	SC	Emissivity	DL Trans	Installed Cost
1	Single Pane Clear Glass	1.061	0.870	0.840	0.000	3.30
2	Double Pane Clear Glass	0.600	0.570	0.800	0.000	12.00
3	Single Plate Reflective	0.800	0.450	0.200	0.000	4.62
4	Double Plate Reflective	0.550	0.250	0.200	0.000	8.55
5	Single Plate Heat Abs.	1.060	0.710	0.840	0.000	0.00
6	Double Plate Heat Abs.	0.550	0.570	0.840	0.000	0.00
7	User's Choice Window	0.000	0.000	0.000	0.000	0.00
8	User's Choice Window	0.000	0.000	0.000	0.000	0.00
9	User's Choice Window	0.000	0.000	0.000	0.000	0.00
10	Plastic Dome Skylight	0.980	0.650	0.840	0.000	11.50
11	Dbl. Glass Skylight	0.520	0.570	0.840	0.470	15.00
12	User's Choice Skylight	0.000	0.000	0.000	0.000	0.00
13	User's Choice Window	0.000	0.000	0.000	0.000	0.00
14	User's Choice Window	0.000	0.000	0.000	0.000	0.00
15	User's Choice Window	0.000	0.000	0.000	0.000	0.00

OK Undo Select

Form 3A.7

RUN ENERGY SIMULATION
Before running the simulation, you can specify the number of weeks per month and the months to be simulated. You can also decide whether you want to use the previously run weather sequence.



VIEW SIMULATION OUTPUT
After the program has completed the simulation, you will be able to view the simulation output by selecting the "View Output" pull-down menu.

This figure shows one of the output reports of ENER-WIN. When you want to quickly find out the simulation results, you may wish to first observe this report because it summarizes the building energy use. This report presents the monthly energy use as well as the annual utility bill and the Energy Utilization Factor (EUF). The latter is the number that you compare to the B.E.P.S. value.

II. MONTHLY SUMMARIES OF ENERGY FOR HEATING AND COOLING. ....PAGE31....

*** PROJECT: Gregory Bateson Building
PLAN: Final TYPE: Office CONSTRUCTION YEAR: 1995.

MON	HEATING LOADS (MMBTU)	SOLAR HEATING FRACTION (SHF)	H.W. LOADS (MMBTU)	COOLING LOADS (MMBTU)	FAN ENERGY REQD. (KWH)	LIGHT and APPL. (KWH)	A.C. COMPR HOURS (HRS)	SYST OPER. HOURS (HRS)	GAS FUEL USE (MMBTU)	GAS FUEL COST ($)	PEAK ELEC DEMAND (KW)	ELEC ENERGY USE (KWH)	TOTAL ELEC COST ($)	TOTAL UTIL BILL ($)	COST PER AREA ($/SQ.FT.)
JAN	87.5	0.42	25.8	0.0	1275.	141587.	0.	251.	161.9	1052.65	627.4	142862.	12616.11	13668.75	0.06
FEB	48.0	0.53	22.0	4.5	862.	124520.	82.	312.	100.0	650.18	475.9	125881.	10270.58	10920.76	0.05
MAR	39.7	0.63	23.6	21.4	1452.	134800.	78.	370.	90.4	587.75	543.3	138627.	11521.61	12109.36	0.05
APR	15.7	0.82	21.6	69.4	2701.	128737.	55.	457.	53.3	346.71	636.4	139146.	12566.18	12912.89	0.06
MAY	1.9	0.97	20.6	232.1	7750.	132550.	97.	528.	32.2	208.98	816.6	166095.	15626.57	15835.55	0.07
JUN	0.1	1.00	18.3	336.4	10022.	126453.	97.	577.	26.3	171.10	961.3	173853.	17528.73	17699.83	0.08
JUL	0.8	0.98	18.0	520.8	15709.	130766.	128.	626.	26.8	174.45	1007.9	204340.	19260.44	19434.89	0.08
AUG	2.4	0.91	18.2	491.3	14991.	132302.	118.	617.	29.5	191.55	993.5	201885.	19003.79	19195.34	0.08
SEP	1.1	0.95	18.5	305.0	9338.	129295.	73.	577.	27.9	181.45	897.4	172526.	16772.64	16954.09	0.07
OCT	0.3	1.00	21.0	203.8	6678.	135525.	49.	485.	30.4	197.46	848.6	164846.	15928.62	16126.08	0.07
NOV	14.9	0.77	23.0	40.4	1675.	134454.	10.	346.	54.1	351.66	615.3	140614.	12392.33	12744.00	0.06
DEC	78.8	0.50	25.8	4.4	1310.	141475.	1.	341.	149.5	971.86	516.3	143279.	11410.99	12382.85	0.05
TOTALS:															
	291.3	0.68	256.4	2229.5	73762.	1592465.	786.	5488.	782.4			1913954.			
($)	2762.		2428.	10023.	2950.	63699.					5086.	98340.	76558.	174899.	179984. 0.78

OUTDOOR LIGHING KWH- 0. 588564. KWH DISPLACED BY DAYLIGHTING - $ 23543. SAVED IN LIGHTING
ENERGY BUDGETS : SITE LINE - 7315. MMBTU (31.8 MBTU/SQ.FT.) ..... SOURCE - 20879. MMBTU (90.7 MBTU/SQ.FT.)

E.U.F.

Annual total Utility Bill

Form 3B.1

CALIBRATION
(Computer results compared to monthly peak electric demands)

CALIBRATING THE PEAK ELECTRIC DEMANDS

Compare the simulated monthly peak demands to the peak demands in the utility records. Try to match the simulated results to within 20% of the monthly and 10% of the annual utility records. Adjust the input and re-run the simulation if necessary. Show what adjustments you are making.

UTILITY RECORDS		COMPUTER SIMULATION RESULTS							
		CYCLE 1		CYCLE 2		CYCLE 3		CYCLE 4	
		ORIGINAL RUN		MODIFICATION 1 _____		MODIFICATION 2 _____		MODIFICATION 2 _____	
MON	PEAK KW	PEAK KW	% DIFF.	PEAK KW	% DIFF.	PEAK KW	% DIFF.	PEAK KW	% DIFF.
JAN									
FEB									
MAR									
APR									
MAY									
JUN									
JUL									
AUG									
SEP									
OCT									
NOV									
DEC									
TOTAL									

Form 3B.2

CALIBRATION
(Computer runs to actual disaggregated data)

CALIBRATING THE ENERGY MODEL:
Compare the individual simulated values to the corresponding disaggregated values from actual data. Try to match the simulated results to within 20% of the utility records and the total to within 10%. Adjust the input and re-run the simulation if necessary. Show what adjustments you are making.

UTILITY RECORDS (ACTUAL ENERGY USE)	COMPUTER SIMULATION RESULTS							
	CYCLE 1		CYCLE 2		CYCLE 3		CYCLE 4	
	ORIGINAL RUN		ADJUSTMENT: _____		ADJUSTMENT: _____		ADJUSTMENT: _____	
	ENERGY	% DIFF.	ENERGY	% DIFF.	ENERGY	% DIFF.	ENERGY	% DIFF.
(a) Fan Motors >> (KWH)								
(b) Lighting >> (KWH)								
(c) Receptacles >> (KWH)								
(d) Water Heating >> (KWH or MMBtu)								
(e) Space Cooling >> (Kwh)								
(f) Space Heating >> (KWH or MMBtu)								
(g) Total Electric >> (KWH)								
(h) Total Gas >> (MMBtu)								
(i) EUF >> (MBtu/sq.ft.yr.)								

Note: After the simulation has been calibrated to the real data, look at the components of energy use in the simulated annual load results. Analyze which load component that contributes the most to the energy use, and start analyzing some retrofit strategies.

BUILDING ENERGY PERFORMANCE STANDARD (B.E.P.S)
(Source Energy - 1000's Btu/sq.ft.yr.)

No	State	SMSA	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	AL	Birmingham	123	107	127	353	166	114	110	161	113	101	89	117	181	142	139	53
2	AL	Mobile	142	129	147	406	192	127	132	187	131	116	96	133	207	166	162	47
3	AZ	Phoenix	146	133	152	406	196	131	136	192	134	119	100	137	212	171	168	49
4	CA	Bakersfield	123	109	127	358	167	113	112	162	113	100	86	116	181	143	140	48
5	CA	Fresno	120	105	123	353	163	112	108	158	111	98	85	114	178	139	136	50
6	CA	Los Angeles	112	101	115	364	157	103	103	151	106	91	74	106	171	132	126	42
7	CA	Sacramento	118	102	120	353	160	110	104	154	108	96	84	112	175	136	132	52
8	CA	San Diego	114	103	117	364	158	104	106	153	107	92	75	107	172	134	128	40
9	CA	San Francisco	108	92	109	353	150	103	94	143	101	87	76	103	165	125	119	51
10	CO	Denver	122	98	123	338	162	119	100	156	109	100	97	118	178	137	135	71
11	CT	Bridgeport	128	105	130	353	170	123	106	156	115	105	100	123	186	144	142	71
12	CT	Hartford	125	101	127	338	165	122	102	159	112	103	100	121	181	140	139	74
13	DC	Washington	127	107	129	353	169	120	109	164	115	104	96	121	185	144	142	63
14	FL	Jacksonville	143	130	149	406	193	128	134	189	132	117	97	134	209	167	164	47
15	FL	Miami	152	142	161	406	203	133	147	201	140	125	103	141	219	179	178	41
16	FL	Tampa	145	135	152	406	196	129	139	193	135	119	98	136	212	171	168	43
17	GA	Atlanta	122	106	125	353	165	114	108	160	112	100	88	116	180	141	138	53
18	ID	Boise City	124	100	125	338	163	120	101	158	111	101	98	120	179	139	137	71
19	IL	Chicago	127	102	129	338	167	124	103	161	113	104	103	123	183	142	141	75
20	IL	Glenview	129	103	130	338	168	125	105	163	114	105	103	124	184	143	143	75

1 Clinic
2 Community Center
3 Gymnasium
4 Hospital
5 Hotel/Motel
6 Multifamily Highrise
7 Multifamily Lowrise
8 Nursing Home
9 Office Large
10 Office Small
11 Elementary School
12 Secondary School
13 Shopping Center
14 Store
15 Theater/Auditorium
16 Warehouse

BUILDING ENERGY PERFORMANCE STANDARD (B.E.P.S)
(Source Energy - 1000's Btu/sq.ft.yr.)

No	State	SMSA	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
21	IN	Indianapolis	128	103	130	338	168	124	105	162	114	105	102	123	184	143	142	73
22	KS	Dodge City	133	109	135	353	175	128	111	162	119	109	105	128	191	150	149	72
23	KY	Louisville	128	107	131	353	170	122	109	165	116	105	98	123	186	145	143	66
24	LA	Baton Rouge	142	129	147	406	192	123	132	188	131	116	97	133	208	166	163	48
25	LA	New Orleans	144	129	149	406	194	130	133	189	132	118	100	135	210	168	164	52
26	ME	Portland	130	100	131	335	169	129	101	162	114	107	109	127	186	143	143	86
27	MA	Boston	125	101	126	338	165	121	102	159	111	102	99	121	181	140	139	72
28	MI	Detroit	129	103	130	338	168	126	104	163	114	106	105	125	185	143	143	77
29	MN	Minneapolis	142	109	144	335	180	140	110	175	123	117	122	138	198	155	157	93
30	MP	Jackson	127	113	131	358	171	117	115	167	117	104	90	120	186	147	145	50
31	MO	Columbia	132	109	134	353	174	126	111	161	118	108	103	127	190	140	148	71
32	MO	Kansas City	133	110	136	353	175	127	112	162	119	109	104	128	191	150	149	70
33	MO	St.Louis	133	110	136	353	175	128	112	163	119	109	105	128	192	150	149	72
34	MT	Great Falls	131	102	132	335	170	129	102	163	115	107	110	127	186	144	144	85
35	NE	Omaha	130	105	132	338	170	126	105	164	115	107	105	126	186	145	145	76
36	NV	Las Vegas	130	115	135	358	174	118	118	170	119	106	92	122	188	150	148	49
37	NJ	Newark	129	107	131	353	171	123	108	165	116	105	99	124	187	146	144	68
38	NM	Albuquerque	127	107	129	353	169	121	108	164	115	104	96	122	185	144	142	64
39	NY	Albany	131	102	132	335	170	129	103	164	115	108	109	127	187	145	145	83
40	NY	Binghamton	133	103	135	335	172	132	104	166	117	110	113	130	189	147	147	88

1 Clinic
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7 Multifamily Lowrise
8 Nursing Home
9 Office Large
10 Office Small
11 Elementary School
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13 Shopping Center
14 Store
15 Theater/Auditorium
16 Warehouse

BUILDING ENERGY PERFORMANCE STANDARD (B.E.P.S)
(Source Energy - 1000's Btu/sq.ft.yr.)

No	State	SMSA	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
41	NY	Buffalo	129	101	130	338	168	127	102	162	114	106	106	125	185	143	142	80
42	NY	New York	126	105	128	353	168	120	107	162	114	103	96	121	184	143	141	66
43	NC	Raleigh	124	106	127	353	167	117	108	161	113	101	92	119	182	142	139	59
44	ND	Bismarck	146	110	147	335	184	146	111	179	125	121	129	143	203	158	161	102
45	OH	Akron	128	102	129	338	167	125	103	161	113	105	104	124	183	142	141	77
46	OH	Cincinnati	130	107	132	353	172	124	109	166	117	106	101	125	188	147	145	70
47	OH	Cleveland	129	103	131	338	169	126	104	163	114	106	105	125	185	144	143	78
48	OH	Columbus	128	103	130	338	168	125	104	162	114	105	103	124	184	143	142	75
49	OK	Oklahoma City	129	110	132	353	172	121	112	167	117	106	97	123	187	147	146	61
50	OK	Tulsa	127	109	130	353	170	119	111	165	116	104	95	121	185	146	144	99
51	OR	Medford	120	99	121	353	162	116	101	155	109	98	91	116	177	136	133	64
52	OR	Portland	119	98	120	353	161	116	99	154	108	97	91	115	176	135	131	66
53	PA	Allentown	129	105	131	353	171	125	106	158	116	106	102	125	187	145	144	74
54	PA	Philadelphia	131	107	133	353	173	126	109	160	117	107	102	126	189	147	146	71
55	PA	Pittsburgh	126	101	127	338	165	122	103	159	112	103	100	121	181	141	139	72
56	SC	Charleston	124	110	128	358	168	114	113	163	114	102	88	118	183	144	141	49
57	TN	Memphis	126	109	129	353	169	117	111	164	115	103	92	120	184	146	142	56
58	TN	Nashville	125	107	128	353	168	117	109	162	114	102	92	119	183	143	141	58
59	TX	Amarillo	126	106	129	353	168	120	108	163	114	103	95	121	184	144	141	63
60	TX	Brownsville	150	139	157	406	200	132	143	198	138	123	101	139	216	176	174	43

1 Clinic
2 Community Center
3 Gymnasium
4 Hospital
5 Hotel/Motel
6 Multifamily Highrise
7 Multifamily Lowrise
8 Nursing Home
9 Office Large
10 Office Small
11 Elementary School
12 Secondary School
13 Shopping Center
14 Store
15 Theater/Auditorium
16 Warehouse

BUILDING ENERGY PERFORMANCE STANDARD (B.E.P.S)
(Source Energy - 1000's Btu/sq.ft.yr.)

No	State	SMSA	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
61	TX	Dallas	131	116	136	358	175	119	119	171	120	107	94	124	190	152	150	50
62	TX	El Paso	126	110	129	358	169	116	113	164	115	103	90	119	184	145	142	52
63	TX	Houston	145	130	150	406	195	130	134	190	133	118	100	136	211	169	166	51
64	TX	Lubbock	126	107	128	353	168	118	110	163	114	103	93	120	183	144	141	58
65	TX	San Antonio	146	131	151	408	196	132	134	191	134	119	102	137	212	170	167	53
66	UT	SaltLake City	129	104	131	338	169	125	105	163	114	106	104	125	185	144	143	76
67	VT	Burlington	134	103	135	335	173	133	104	167	117	110	114	131	190	147	148	89
68	VA	Norfolk	123	105	125	353	165	115	108	160	112	100	90	117	180	141	138	56
69	VA	Richmond	129	107	131	353	171	122	109	165	116	105	98	123	186	146	144	66
70	WA	Seattle	119	96	119	353	160	116	97	153	107	96	91	115	176	134	130	69
71	WA	Spokane	126	99	126	338	165	124	100	158	111	103	103	122	181	139	138	79
72	WV	Charleston	128	106	130	353	170	123	108	164	115	105	99	123	186	145	143	68
73	WI	Madison	131	102	132	335	170	130	103	164	115	108	110	128	187	145	145	84
74	WI	Milwaukee	131	102	132	335	170	129	103	164	115	108	110	128	187	145	145	84
75	WY	Cheyenne	128	100	129	338	167	127	101	161	113	105	106	125	184	142	141	82

1 Clinic
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13 Shopping Center
14 Store
15 Theater/Auditorium
16 Warehouse

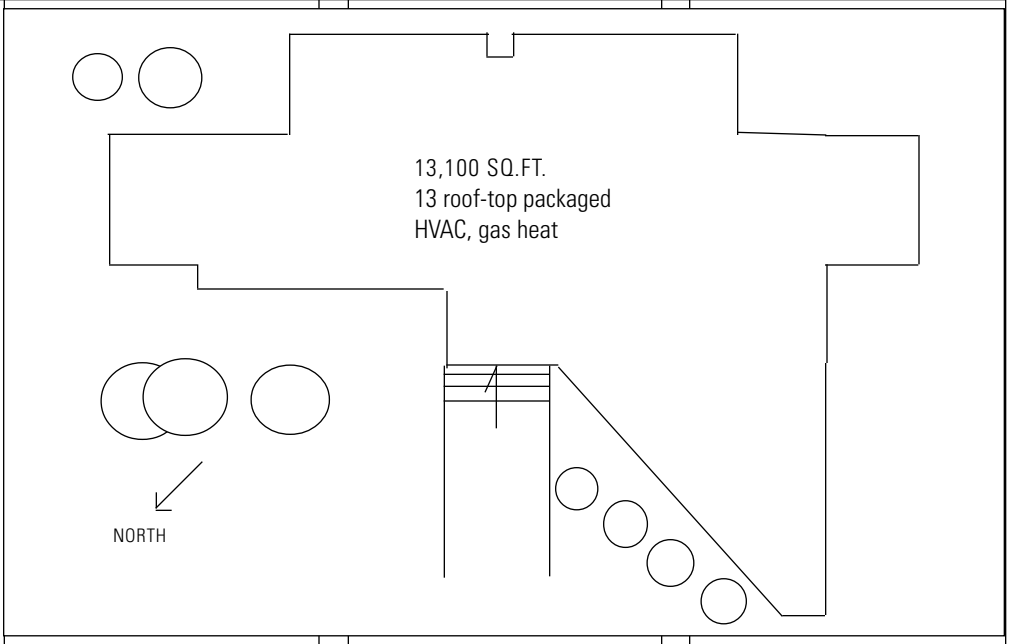
Form 1A.1

PROJECT INFORMATION
Field Preparation

PROJECT INFORMATION
Use this form to collect and document general data of your building.

YOUR NAME	YOUR NAME	YOUR NAME
STUDENT 1	STUDENT 2	
PROJECT NAME: COLLEGE STATION CONFERENCE CENTER		BUILDING TYPE: COMMUNITY CTR./SCHOOL
PROJECT DESCRIPTION: 1-STORY BRICK VENEER, R-27 ROOF PACKAGED HVAC		
PROJECT LOCATION: COLLEGE STATION		STATE: TEXAS ZIP:
YEAR OF CONSTRUCTION: 1992 (RENOVATION)	TOTAL FLOOR AREA (SQ.FT.): 13,100	CONSTRUCTION COST ($/SQ.FT.)): 35.00 (APPROX)
TOTAL OCCUPIED DAYS/WEEK: 6	ANNUAL HOLIDAYS (DAYS): 10	CIRCLE MONTHS WHEN VACANT: 1 2 3 4 5 6 7 8 9 10 11 12

CASE STUDY BUILDING
Sketch your building or attach the photograph of your case study building.



CONTACTS
Place your principal contacts and their telephone numbers here.

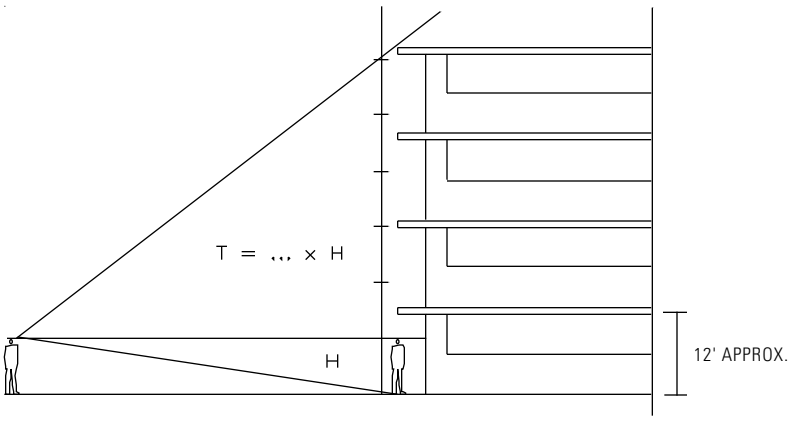
BUILDING OPERATOR		TELEPHONE
ARCHITECT		TELEPHONE
MECHANICAL ENGINEER		TELEPHONE
ENERGY CONSULTANT		TELEPHONE

Form 1B.1

METHODS FOR ESTIMATING BUILDING HEIGHT
Field Preparation

The following figures show two methods to estimate the building's height when drawings are not available. You need at least two people to do either of these methods and a stick or a helium balloon.

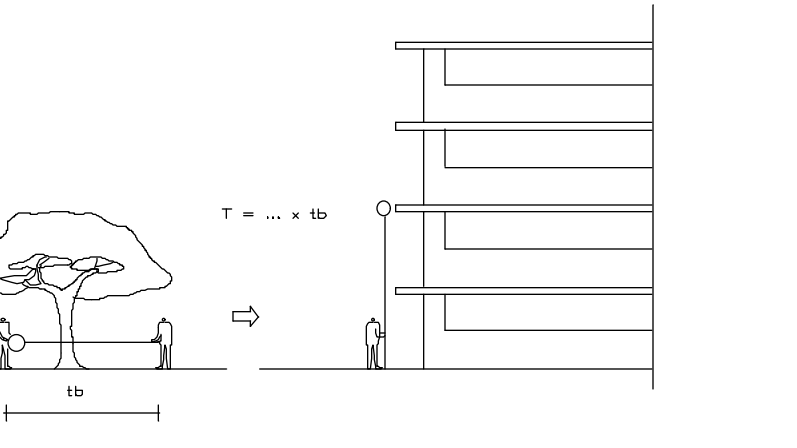
METHOD I
Ask a person, whose height is known, to stand closely to the building. Or use a stick with a known length, and put it close the building. Estimate the building's height by determining multiples of the height ot that person or the stick.



1 STORY BUILDING = 12' HIGH

METHOD II
Use a helium balloon and tie it to a long cord. Hold the cord and let the balloon go up straight until it reaches the point where the balloon is at the same height as the building. Put a mark on the cord at the point where it touches the ground. Pull the balloon down and measure the distance between the balloon and the mark on the cord.

This method is practical for heights up to 50 feet. At higher levels, wind may become a problem.

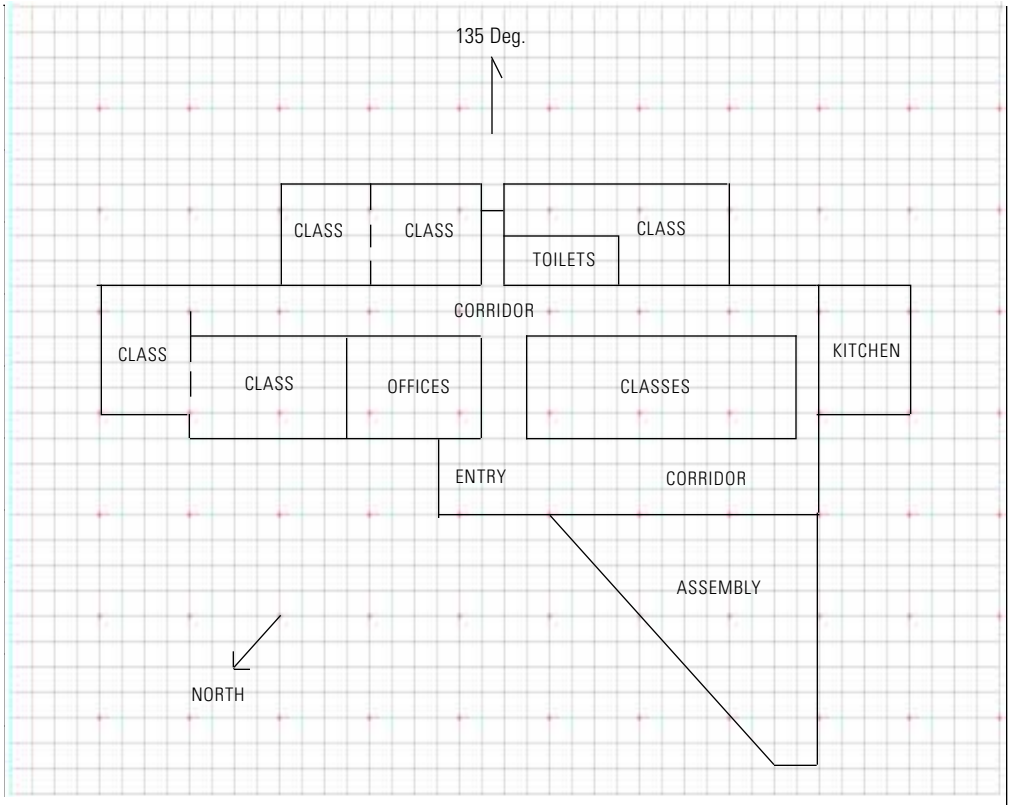


Form 1B.2

BUILDING SKETCH
Showing HVAC Zones

BUILDING SKETCH
Use this grids to sketch the floor plan of your building. Copy this sheet if you have more than one floor, and sketch each different floor plan on a separate sheet.

Sketch the floor plan according to the HVAC zones. You do not have to sketch the floor plan exactly the same as drawn in the architectural/shop drawing of this building.



NOTATIONS
Write the scale or grid size of your sketch. Also write the building orientation (in degrees from North), total building area, floor area of this plan, the level number, average ceiling height, and the number of floors typical of this floor plan.

SCALE / GRID SIZE (FEET PER GRID) 6				TOTAL BUILDING AREA 13,100
BLDG. ORIENTATION (FROM NORTH) 135				AVE. CEILING HEIGHT (FEET) 10
LEVEL NUMBER 1		FLOOR AREA OF THIS PLAN (FT2) 13,100		NO. OF FLOORS TYPICAL OF THIS PLAN 1
NOTES ALL SPACES ARE HEATED AND COOLED		13 ROOF TOP HVAC UNITS		

If the building has more than one typical floor,
COPY THIS SHEET TO SKETCH DIFFERENT FLOOR PLANS

Form 1C.1

UTILITY BILL RECORDS

UTILITY BILL RECORDS
Using the monthly utility records of your building, write the following values for each month: KWH electric use, KW peak, Electric Energy Charge, Electric Peak Demand Charge, and Therms of gas and cost of gas if the building uses gas for heating.

(a) MONTH	(b) KWH ELECTRIC	(c) KW PEAK	(d) ELECTRIC ENEGY CHARGE	(e) ELECTRIC PEAK DEMAND CHARGE	(f) THERMS OF GAS USED	(g) COST OF GAS
JAN	11,160	48.0	237	576	2000	989
FEB	13,320	49.2	280	590	998	530
MAR	13,680	54.0	287	648	851	453
APR	16,200	70.8	337	850	57	41
MAY	16,320	62.4	340	749	4	13
JUN	23,280	96.0	478	1152	2	8
JUL	25,440	79.2	521	950	1	7
AUG	27,240	80.4	557	965	1	7
SEP	24,280	79.2	509	950	1	7
OCT	16,920	66.0	352	792	3	8
NOV	11,520	51.6	244	619	50	36
DEC	13,920	49.2	292	590	950	505
TOTALS	213,840	786	4435	9432	4918	2605
			(d)/(b) =	**(e)/(c) =**		**(g)/(f) =**
			$ 0.021 / KWH	$ 12 / KW		$ 0.53 / THERM

COST PER UNIT
Divide total annual cost by consumption to get the cost per unit.

ENERGY UTILIZATION FACTOR
Calculate the Energy Utilization Factor (EUF) and then compare the result with B.E.P.S. (Appendix A).

$$\textbf{EUF} = \frac{213{,}840\ \textbf{Kwh x 10,500} + 4{,}918\ \textbf{Therms x 100,000}}{13{,}100\ \textbf{sq.ft. x 1,000}}$$

EUF = 209 **MBtu/sq.ft.**

B.E.P.S. = 134 **MBtu/sq.ft.**

↓

AVERAGE OF COMMUNITY CENTER (131) AND SECONDARY SCHOOL (137) FOR SAN ANTONIO

Form 2A.1

ECONOMICS DATA

ECONOMICS DATA
Use this form to collect and document the economics data of your case study building.

BUILDING ECONOMIC LIFE (YEARS) 15	MECHANICAL SYSTEM LIFE (YEARS) 15	
DISCOUNT RATE 0.06	BUILDING COST ESCALATION RATE 0.07	
ELECTRIC COST ($/KWH) 0.021	ELECTRIC COST ESCALATION RATE 0.05	
GAS COST ($/THERM) 0.53	GAS COST ESCALATION RATE 0.03	
WATER COST ($/1000 GALLON) 2.00	WATER COST ESCALATION RATE 0.03	

DEMAND CHARGE RATE STRUCTURE

KW	$/KW
1.0	24.00
100.	12.00

CONTACTS
Place the utility company name, contact persons and their telephone numbers here.

UTILITY COMPANY (ELECTRIC) CITY OF	ADDRESS TEXAS AVENUE	
COLLEGE STATION	CONTACT PERSON UTILITY CO.	TELEPHONE
UTILITY COMPANY (GAS) LONESTAR GAS	ADDRESS BRYAN	
	CONTACT PERSON	TELEPHONE
UTILITY COMPANY (WATER) CITY OF	ADDRESS	
COLLEGE STATION	CONTACT PERSON UTILITY CO.	TELEPHONE

Form 2B.1

THERMAL PROPERTIES OF THE ENVELOPE

WALL AND ROOF PROPERTIES
By analyzing the material assemblies, try to estimate the properties of the walls and roofs: U-Factor, Solar Absorptivity, Time Lag, Decrement Factor, and Installed Cost.

You can also use the data from literature listed in the Annotated Bibliography.

If you do not know the decrement factor, just enter 0 (zero).

WALL AND ROOF PROPERTIES

NO.	DESCRIPTION	U-FACTOR	SOLAR ABSORPTIVITY	TIME LAG (HRS.)	DECREMENT FACTOR	INSTALLED COST ($/SQ.FT.)
3	UNINS. BRICK VENEER	0.11	0.75	3.0	0.0	9.00
9	R-27 BUILT-UP ROOFING	0.037	0.75	1.0	0.0	7.00
10	R-9 VAULTED ROOF	0.11	0.75	1.0	0.0	8.00
13	R-19 FLOOR	0.06	0.0	2.0	0.0	5.00

WINDOW AND SKYLIGHT PROPERTIES
By analyzing the glazing assemblies, try to estimate the properties of the windows and skylights: U-Factor, Solar Heat Gain Factor, Emissivity, Daylight Transmissivity, and Installed Cost.

You can also use the data from literature listed in the Annotated Bibliography.

WINDOW AND SKYLIGHT PROPERTIES

NO.	DESCRIPTION	U-FACTOR	SOLAR HEAT GAIN FACTOR	EMISSIVITY	DAYLIGHT TRANSMISSIVITY	INSTALLED COST ($/SQ.FT.)
1	SINGLE PANE W/ TINT	1.06	0.57	0.84	0.65	5.00

Form 2C.1

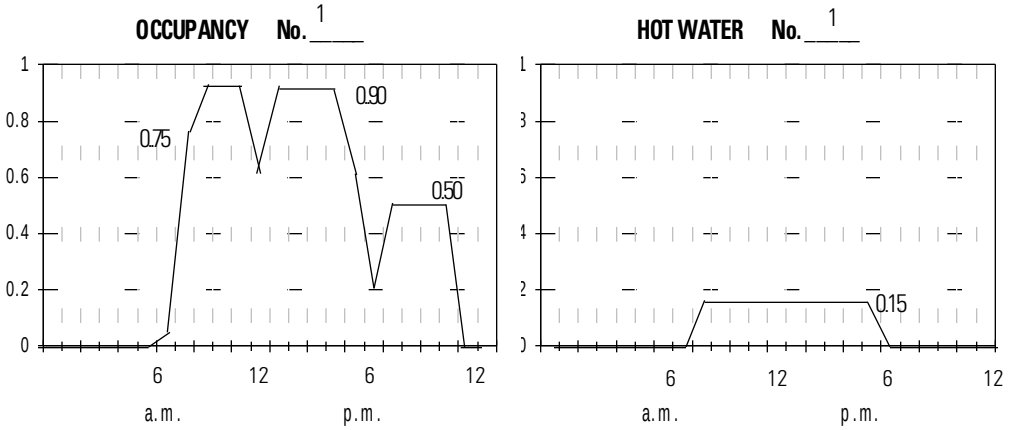
OPERATING SCHEDULES

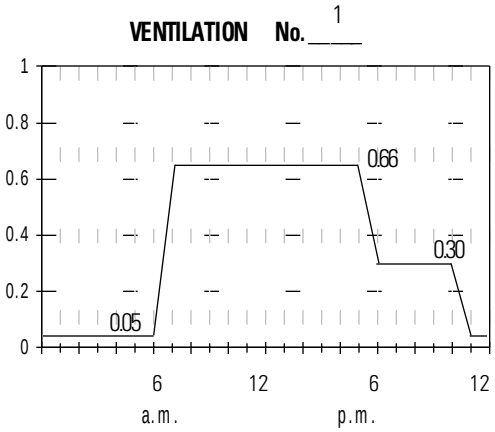
OCCUPANCY PROFILES
Sketch the 24-hour profile of the occupancy in decimal fractions of the value when the occupancy is at the peak. For example, if the building is fully-occupied, the value is 1 (for 100 percent). If the building is half-occipied, the value is 0.5.

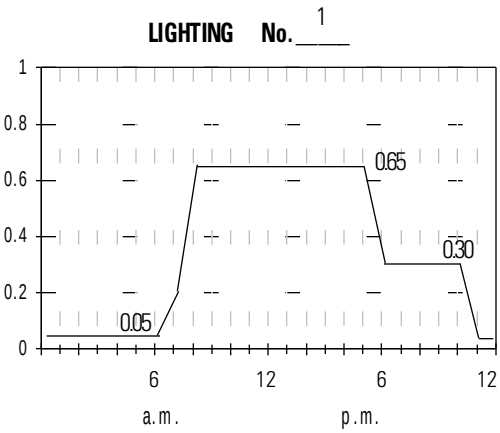
HOT WATER
Sketch the 24-hour profile of the hot water usage in decimal fractions of the peak hot water usage.

VENTILATION
Sketch the 24-hour profile of the ventilation in decimal fractions of the value when the ventilation is at the peak. However, usually the value is either 0 or 1. 0 means the fan is off and 1 means the fan is on.

LIGHTING
Sketch the 24-hour profile of the lighting in decimal fractions of the value when the lighting load is at the peak.







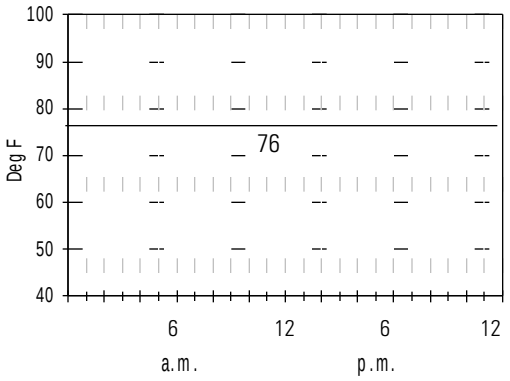
COPY THIS SHEET IF NECESSARY

Form 2C.2

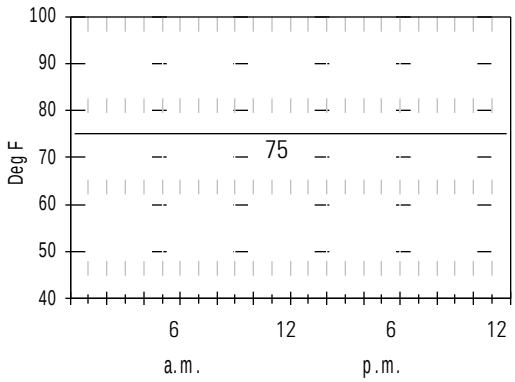
TEMPERATURE SETTINGS

TEMPERATURE SETTINGS
Sketch the 24-hour temperature settings in degrees Fahrenheit (they are the actual temperature settings and not in decimal fractions). Sketch the profiles for four different conditions: summer occupied, winter occupied, summer unoccupied, and winter unoccupied.

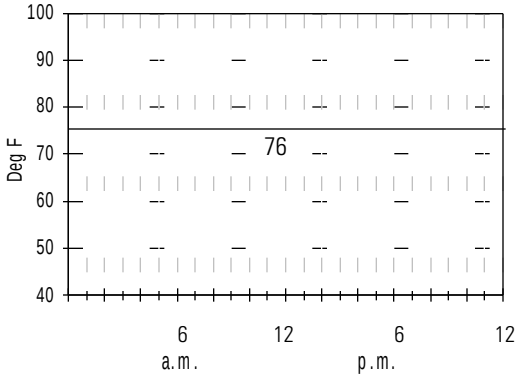
SUMMER OCCUPIED No. 1



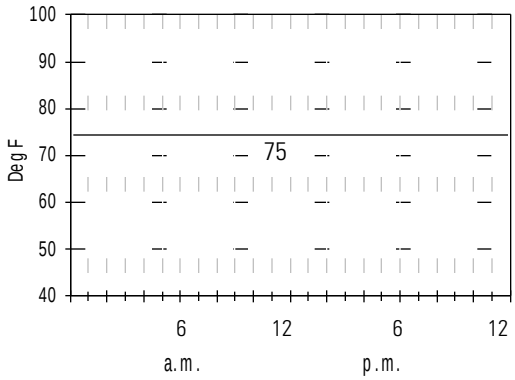
WINTER OCCUPIED No. 2



SUMMER OCCUPIED No. 1



WINTER OCCUPIED No. 4



COPY THIS SHEET IF NECESSARY

Form 2D.1

ZONE DESCRIPTIONS
(Copy this sheet for each zone)

GENERAL ZONE DATA Record the general data only for this zone.	ZONE NO. 7	ZONE NAME ASSEMBLY HALL			
	ZONE AREA (SQ.FT.) 2664	INTERNAL MASS (PSF) 50	INFILTRATION RATE (ACH) 0.8		
LOADS, PROFILES, AND TEMPERATURE SETTINGS Record the loads and profiles of the occupancy, hot water, ventilation and lighting. Also record the temperature settings.	NO. OF OCCUPANTS 100	HOT WATER (GALLON/ PERSON/DAY) 0.5	VENTILATION (CFM/ PERSON) 15	LIGHTING (WATT/ SQ.FT.) 1.7	EQUIP. (WATT/ SQ.FT.) 0.23
	OCCUPANCY PROF. NO. 1	HOT WATER PROF. NO. 1	VENTILATION PROF. NO. 1	LIGHTING & EQUIP. PROF. NO. 1	
	SUMMER OCCUPIED TEMP. SETTING NO. 1	WINTER OCCUPIED TEMP. SETTING NO. 2	SUMMER UNOCCUPIED TEMP. SETTING NO. 3	WINTER UNOCCUPIED TEMP. SETTING NO. 4	
HVAC SYSTEMS Record the data of the HVAC systems.	ECONOMIZER CYCLE (Y/N) N	NATURAL VENTILATION (Y/N) N	NATURAL VENTILATION RATE (CFM/SQ.FT.) 0		
	AC TYPE 5 (ROOF TOP)	COOLING SEER 8.5	HEATING TYPE 1 (GAS)	HEATING COP 0.75	
	HVAC FIRST COST ($/TON) 700	MAINTENANCE COST ($/TON/YEAR) 31.5			
LIGHTING SYSTEMS Record the lighting systems.	LIGHTING TYPE 1 (FLUORESCENT)	LIGHTING COST ($/SQ.FT.) 2.50	ZONE DEPTH FOR DAYLIGHTING 15 FEET	TARGET LIGHTING LEVEL (FOOTCANDLES) 40	

ZONE SKETCH

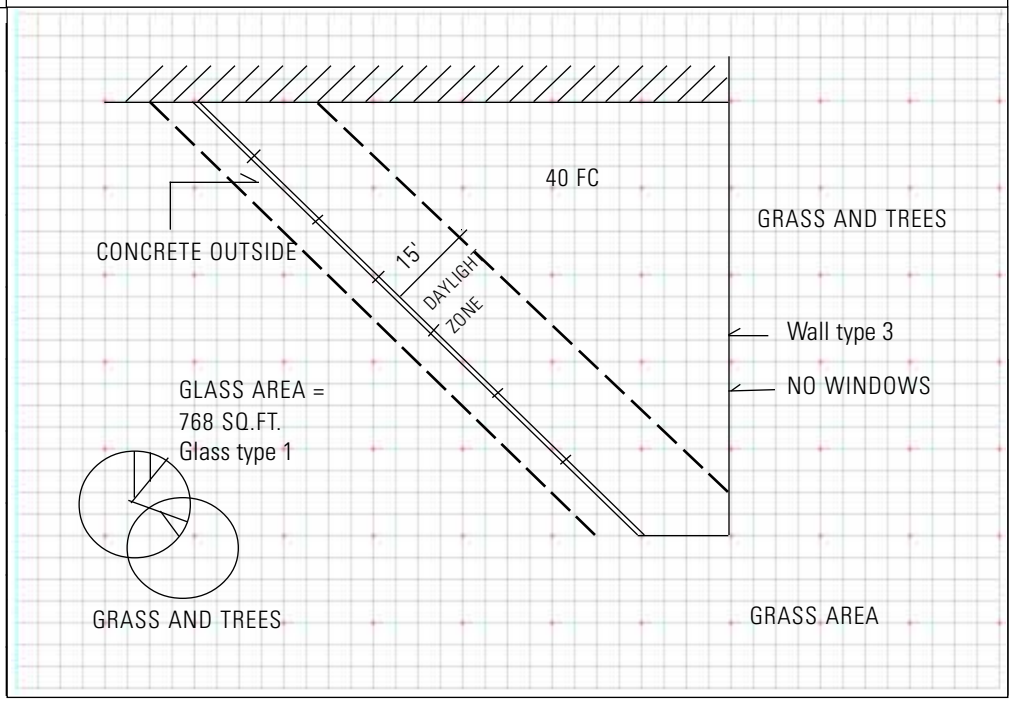
Sketch this zone only. Try to include all data on the sketch, such as: the wall and window material and areas, the type(s) of exterior ground surface and wall exposure, and any other necessary data if daylight is used:

SILL HEIGHT = 3' FT.

TOP OF WINDOW HEIGHT = 9' FT

GROUND REFLECTANCE = _____

WINDOW SHADE TRANSMISSIVITY = _____

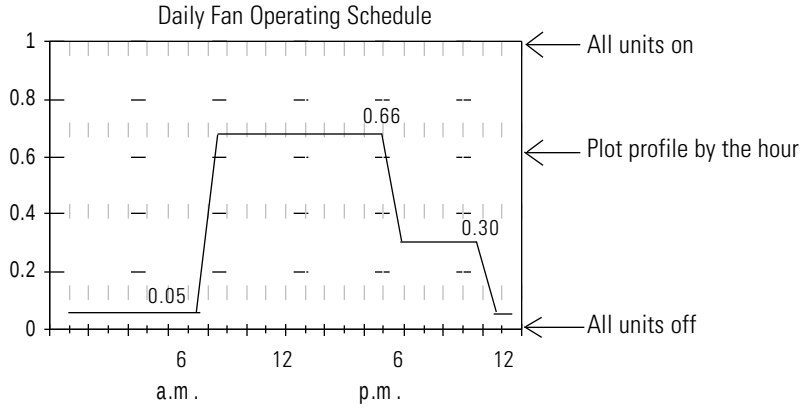


Form 2E.1

DISAGGREGATION OF ACTUAL ENERGY USE

(a) Fan Motors (QF):

FAN OPERATING SCHEDULE
Sketch the 24-hour operating schedule of the fan in decimal fraction of the peak fan motor usage.



FAN OPERATING ENERGY
Calculate the annual energy (in KWH/yr) for fan motors by filling the blanks.

Daily Operating Hours (DOH) = $\sum_{i=1}^{24}$ profile $_i$ = 7.5 hrs / day

Check one: F = 1 V Constant Volume Fans (SINGLE SPEED)

F = 0.8 40 - 5040 - 50 _____ Variable Volume Fans

Fan KW: KW max = 0.75 x _____ h.p. = _____ KW

or √ from equipment specs supplied by contractor

KW max = _____ Volts x _____ Amps / 1000 = 9.23 KW

KW ave = $\frac{9.23}{\text{KWmax}}$ x $\frac{1}{\text{F}}$ = 9.23 KW

Fan Energy (QF):

KWH/day = $\frac{9.23}{\text{KWave}}$ x $\frac{7.5}{\text{DOH}}$ = 69.23 KWH / day

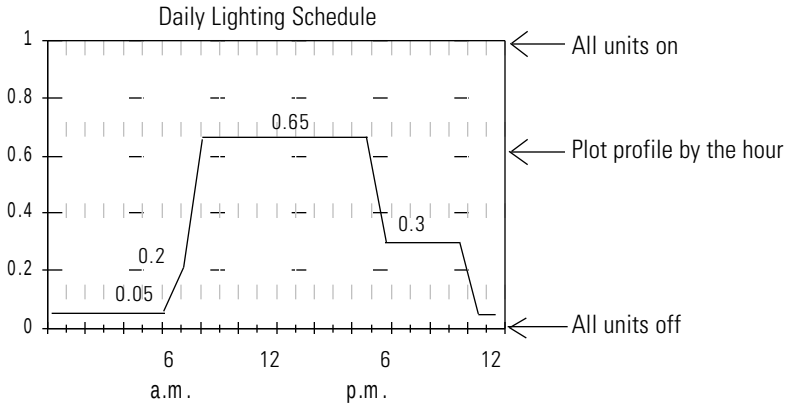
QF = $\frac{69.23}{\text{KWH/day}}$ x $\frac{300}{\text{occ.days/yr.}}$ = 20,769 KWH / yr.

Form 2E.2

DISAGGREGATION OF ACTUAL ENERGY USE (Cont'd..)

(b) Lighting (QL):

LIGHTING SCHEDULE
Sketch the 24-hour operating schedule of the lights in decimal fraction of the peak lighting usage.



LIGHTING ENERGY
Calculate the annual energy (in KWH/yr) for lighting by filling the blanks.

Daily Lighting Hours (DLH) = $\sum_{i=1}^{24}$ profile = 8.6 hrs

Check one: F = 1 _____ Incandescent Lights

F = 1.25 V Fluorescent Lights

Peak KW: KW max = 1.25 / F x 40 watts/lamp x 630 no. of lamps / 1000 = 31.5 KW

Lighting Energy (QL):

KWH/day = 31.5 KWmax x 8.6 DLH = 270.9 KWH

QL = 270.9 KWH/day x 6 occ.days/wk x 50 weeks/yr. = 81,270 KWH / yr.

Form 2E.3

DISAGGREGATION OF ACTUAL ENERGY USE (Cont'd..)

RECEPTACLE ENERGY
Calculate the annual energy (in KWH/yr) for receptacles by by filling the blanks.

(c) Receptacles (QE):

Total Receptacle Watts (EW) = 3000 Watts

Power Density (PD) = 3000 (EW) / 13,100 (Bldg. Area (sq.ft.)) = 0.23 W/sq.ft.

Receptacle KW = 3000 (EW) / 1000 = 3.0 KW

KWH / day = 3.0 (Equip. KW) x 8.6 (DLH) = 25.8 KWH / day

Receptacle Energy (QE):

QE = 25.8 (KWH/day) x 6 (occ.days/wk) x 50 (weeks/yr.) = 7,740 KWH / yr.

WATER HEATING ENERGY
Calculate the annual energy (in Btus or KWH/yr) for water heating by filling the blanks.

(d) Water Heating (QWH):

QD = 187 (Occupants) x 0.5 (Gal/day/person) x 8.33 x (140 - 60 (Ground Temp.)) x 300 (occ.days/yr.)

= 18,692,520 Btus / yr.

Water Heating Energy (QWH):

QWH gas = 18,692,520 (QD) / 0.65 (Efficiency of Heater) = 28.76×10^6 Btus

or

QWH elec. = _____ (QD) / 3413 = _____ KWH / yr.

Form 2E.4

DISAGGREGATION OF ACTUAL ENERGY USE (Cont'd..)

SPACE COOLING ENERGY
Calculate the annual energy (in KWH/yr) for cooling by filling the blanks. Notice that the calculation for gas-heated building is different than for electrically-heated building.

(e) Space Cooling (QC):

- Gas Heated Building.

QC = 213,840 (Total annual KWH) - 20,769 (QF, fans) - 81,270 (QL, lights) - 7,740 (QE, receptacles) - 0 (QWH elec., hot water)

= 104,061 KWH / yr.

- Electrically Heated Building.

Monthly KWH for fans + lights + receptacles + hot water =

QM = (_____ (QF) + _____ (QL) + _____ (QE) + _____ (QWH elec.)) / 12 = _____ KWH /month

Neutral Months, Balance Temperature Range (tb) = 40 - 50 deg. F

AVERAGE MONTHLY TEMPERATURES
Fill the blanks below with the average monthly temperatures. Use these to help determine the neutral months.

MONTH	AVG. TEMP.
Jan.	53.1
Feb.	58.7
Mar.	68.5
Apr.	75.0
May	81.2
Jun.	84.4
Jul.	84.4
Aug.	79.0
Sep.	69.3
Oct.	58.9
Nov.	52.0
Dec.	49.8

	NAME OF MONTH	TOTAL ELEC.	ELEC. USED FOR a, b, c, d (QM)	ELEC. FOR HEATING & COOLING	ELEC. FOR COOLING (KWH)
Neutral Months	_____	_____	_____ - _____ =	_____ x 1/2 =	_____
	_____	_____	_____ - _____ =	_____ x 1/2 =	_____
Other Months > tb	_____	_____	_____ - _____ =		_____
	_____	_____	_____ - _____ =		_____
	_____	_____	_____ - _____ =		_____
	_____	_____	_____ - _____ =		_____
	_____	_____	_____ - _____ =		_____
					_____ +

QC elec. Total = _____KWH/yr

Form 2E.5

DISAGGREGATION OF ACTUAL ENERGY USE (Cont'd..)

SPACE HEATING ENERGY
Calculate the annual energy (in KWH/yr) for space heating by filling the blanks. Notice that the calculation for gas heated building is different than for electrically-heated building.

(f) Space Heating (QH):

- Gas Heated Building.

QH gas = $\frac{491.8 \times 10^6}{\text{Total annual gas Btus}} - \frac{28.76 \times 10^6}{\text{QWH gas}}$

= $\frac{463.04 \times 10^6}{}$ Btus

- Electrically Heated Building.

Monthly KWH for fans + lights + receptacles + hot water =

QM = (_____ + _____ + _____ + _____) / 12 = _____ KWH /month
(QF, QL, QE, QWH)

AVERAGE MONTHLY TEMPERATURES
See Form 2E.4 for average monthly temperatures.

Neutral Months, tb = 40 - 50 deg. F

	NAME OF MONTH	TOTAL ELEC.		ELEC. USED FOR a, b, c, d (QM)		ELEC. FOR HEATING & COOLING		ELEC. FOR HEATING (KWH)
Neutral Months	_____	_____	-	_____	=	_____	x 1/2 =	_____
	_____	_____	-	_____	=	_____	x 1/2 =	_____
Other Months < tb	_____	_____	-	_____	=			_____
	_____	_____	-	_____	=			_____
	_____	_____	-	_____	=			_____
	_____	_____	-	_____	=			_____
	_____	_____	-	_____	=			_____
	_____	_____	-	_____	=			_____
								_____ +

QH elec. Total = _____KWH/yr.

Form 2E.6

DISAGGREGATION OF ACTUAL ENERGY USE (Cont'd..)

ENERGY SUMMARIES
Write the energy used for each category: fan motors, lighting, receptacles, water heating, space cooling, and space heating.

Multiply all electricity KWH with 3,413 to obtain the **Site Btus.** Do not modify any of the gas Btus. Record gas Btus directly in the "Site Btus" column. Compute the total of all Site Btus and then compute the % in each category.

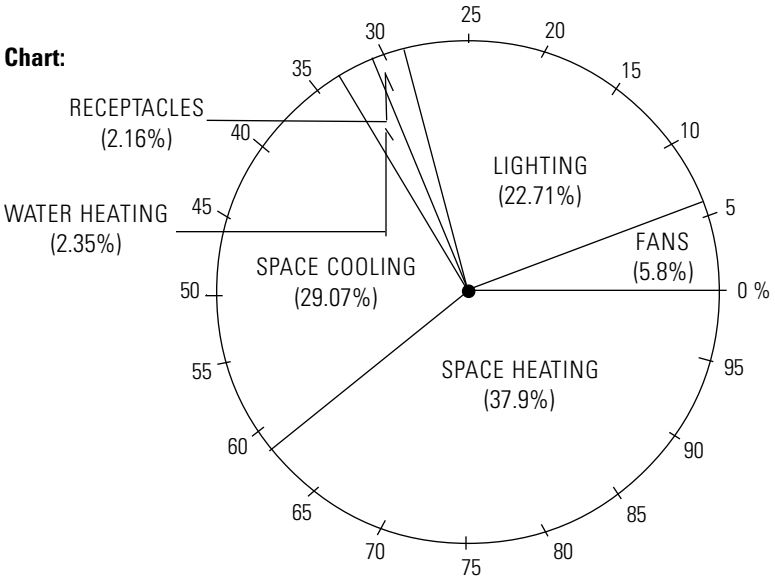
(g) Energy Summaries

CATEGORY		ELECTRIC KWH		SITE BTUS	% OF TOTAL
Fan Motors		20,769	x 3,413	70.88×10^6	5.80 %
Lighting		81,270		277.37×10^6	22.71 %
Receptacles		7,740		26.42×10^6	2.16 %
Water Heating	Gas			28.76×10^6	2.35 %
	Elec.	-		-	
Space Cooling		104,061		355.16×10^6	29.07 %
Space Heating	Gas			463×10^6	37.90 %
	Elec.	-		-	
TOTALS				$1,221.59 \times 10^6$	100 %

Transfer these data to Form 3B.2

PIE CHART OF ENERGY USE
Make the pie chart that shows the energy used by each category. Simply draw lines to separate the category, and write the percentage inside the area of each category.

Pie Chart:



Form 3B.1

CALIBRATION
(Computer results compared to monthly peak electric demands)

CALIBRATING THE PEAK ELECTRIC DEMANDS

Compare the simulated monthly peak demands to the peak demands in the utility records. Try to match the simulated results to within 20% of the monthly and 10% of the annual utility records. Adjust the input and re-run the simulation if necessary. Show what adjustments you are making.

UTILITY RECORDS		COMPUTER SIMULATION RESULTS							
		CYCLE 1		CYCLE 2		CYCLE 3		CYCLE 4	
		ORIGINAL RUN **FAN S.P. = 1.75**		MODIFICATION 1 **FAN S.P. = 2.1** _____		MODIFICATION 2 _____		MODIFICATION 2 _____	
MON	PEAK KW	PEAK KW	% DIFF.	PEAK KW	% DIFF.	PEAK KW	% DIFF.	PEAK KW	% DIFF.
JAN	48	43.8	-9	40.2	-16				
FEB	49.2	47.1	-4	43.8	-11				
MAR	54	50.3	-7	45.0	-17				
APR	70.8	68.2	-4	64.1	-9				
MAY	62.4	83.2	+33	77.5	+24				
JUN	96	97.1	+1	91.3	-5				
JUL	79.2	98.7	+25	93.4	+18				
AUG	80.4	97.5	+21	92.5	+15				
SEP	79.2	99.1	+25	92.8	+17				
OCT	66	72.5	+10	64.5	+2				
NOV	51.6	55.6	+8	51.9	+1				
DEC	49.2	46.6	-5	42.9	-13				
TOTAL	786	859.7	+9	800.0	+2				

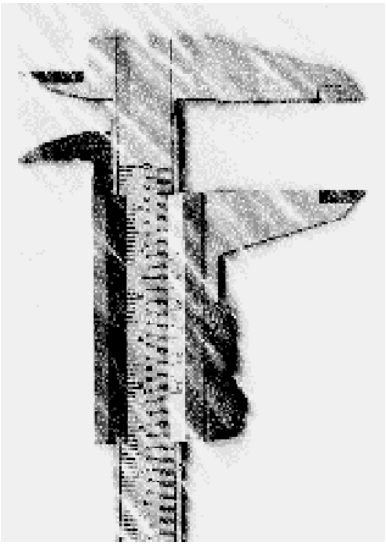
Form 3B.2

CALIBRATION
(Computer runs to actual disaggregated data)

CALIBRATING THE ENERGY MODEL:
Compare the individual simulated values to the corresponding disaggregated values from actual data. Try to match the simulated results to within 20% of the utility records and the total to within 10%. Adjust the input and re-run the simulation if necessary. Show what adjustments you are making.

	UTILITY RECORD	COMPUTER SIMULATION RESULTS							
		CYCLE 1		CYCLE 2		CYCLE 3		CYCLE 4	
		ORIGINAL RUN		ADJUSTMENT: **EXTEND OCCUPANCY ~~REDUCE HW~~**		ADJUSTMENT: _____		ADJUSTMENT: _____	
		ENERGY	%DIFF.	ENERGY	% DIFF.	ENERGY	% DIFF.	ENERGY	% DIFF.
(a) Fan Motors **>>** (KWH)	20,769	11,614	-44	13,181	-36				
(b) Lighting **>>** (KWH)	81,270	81,776	+1	87,434	+8				
(c) Receptacles **>>** (KWH)	7,740	7,911	+2	8,379	+8				
(d) Water Heating **>>** (KWH or MMBtu)	28.76	37.8	+30	27.7	-3				
(e) Space Cooling **>>** (KWH)	104,061	82,438	-20	85,988	-17				
(f) Space Heating **>>** (KWH or MMBtu)	463.04	396.4	-14	437.7	-5				
(g) Total Electric **>>** (KWH)	213,840	183,771	-14	194,104	-9				
(h) Total Gas **>>** (MMBtu)	491.8	434.2	-11	465.4	-5				
(i) EUF **>>** (MBtu/sq.ft.yr.)	209	180.1	-14	190.7	-9				

Note: After the simulation has been calibrated to the real data, look at the components of energy use in the simulated annual load results. Analyze which load component that contributes the most to the energy use, and start analyzing some retrofit strategies.



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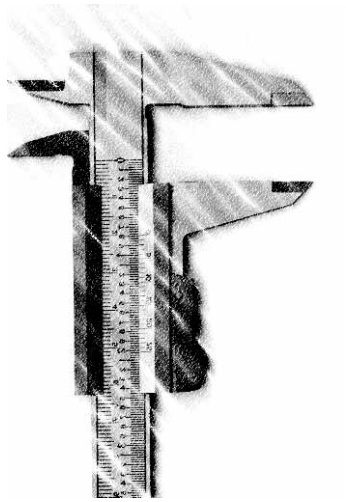

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